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Analysis of the Role of ATC in the AILS Process

NASA Ad Hoc Team Report on ATC in IMC Close Parallel Runway Operations

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Preface

This document represents the report of a NASA Langley Research Center AILS ATC Ad Hoc Team established to initiate development of the concepts necessary to integrate the proposed Airborne Information for Lateral Spacing (AILS) process into the air traffic control (ATC) system in terminal area operations. It was recognized from the outset that the Team could not resolve all of the issues which would surface in the time allotted for its initial work. It was believed that generating a document highlighting the issues and suggesting answers to some of the ATC related questions would be a useful start. It is expected that this document will present a platform from which additional development can be launched, and that it will stimulate experts and stakeholders in the close parallel runway approach problem to start addressing the issues in the necessary detail to bring the AILS process to reality in the National Airspace System.

Three experiment plans are presented to help stimulate the thinking of those who have more experience in conducting ATC experiments. It is anticipated that experiments actually conducted may be significantly different from those proposed here. Nevertheless, the ideas of the Team are presented for initial consideration. One of the important aspects of the experiments is that their design has provided an incentive to explore realistic issues related to how the AILS process might be tailored to fit into different terminal areas. This exercise has highlighted the need to study the AILS process in realistic airspace environment models.

The AILS ATC Ad Hoc Team members are Marvin Waller, Thomas Doyle, and Frank McGee. Marvin Waller has been involved in the AILS process concepts development for the last five years and provided the team with the background information related to the AILS process from the flight deck perspective. Tom Doyle, Adsystech, Inc., is a recently retired FAA Air Traffic Controller with extensive experience in ATC facility management. His most recent experience has been at the Dallas-Fort Worth TRACON and Tower as Manager of Operations. His involvement on the Ad Hoc Team is jointly sponsored by NASA and the FAA. Frank McGee, Lockheed Martin, is a retired United States Navy Master Chief Air Traffic Controller. His background includes facility supervision and experience as an Air Traffic Control Safety Analyst conducting safety inspections at military installation world wide. He was also Master Training Specialist responsible for Control Tower Operator certification. As well as bringing extensive ATC expertise to the team Tom Doyle and Frank McGee used a number of contacts with individuals at ATC facilities throughout the country to update information on the details of current operations in various terminal areas.

A number of individuals at various ATC terminal facilities provided the information assembled in this document through telephone conversations and through providing copies of relevant sections of their operations handbooks. Air traffic staff members at Seattle-Tacoma International airport, San Francisco International airport, Bay TRACON located in Oakland, CA, Dallas-Fort Worth International airport, Minneapolis-St. Paul International airport and St. Louis/Lambert International airport provided extensive detail input that was invaluable in developing this document.

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1.0 Introduction

This paper presents the requirements for Airborne Information for Lateral Spacing (AILS) approaches to closely spaced parallel runways from an ATC perspective. It describes the ATC interaction and requirements for three versions of approaches to closely spaced parallel runways: straight-in approaches, segmented approaches, and paired-staggered approaches. The approaches will be described from the ATC perspective and some of the detailed ATC system considerations in designing the approaches will be addressed in the discussions. Critique and comments on the role of ATC as represented in the document are encouraged. Note: Straight-In approach is used to characterize the difference between the segmented or offset approach.

Independent straight-in approaches in all weather conditions are the baseline for AILS approaches. They are somewhat similar to visual approaches on an IFR flight plan in that responsibility for lateral separation has been handed off by the controller to the flight deck crew. The assumption is that AILS equipment will support the flight deck crew in maintaining separation from traffic on the parallel approach and that Traffic alert and Collision Avoidance System (TCAS) will assist in maintaining separation from other traffic operating in the area. The assumed airborne equipment includes an accurate flight path management system based on technology such as differential Global Positioning System (DGPS) and data communication between aircraft such as with Automatic Dependent Surveillance Broadcast (ADS-B). It also includes an alerting and warning system that will warn of own aircraft deviating from its assigned airspace and of parallel traffic deviating from its airspace in a manner that poses a collision threat involving the own aircraft. A display of proximate traffic may be incorporated in the airborne system. Also, procedures for taking evasive action in the event of intrusions are clearly defined. Conventional TCAS will continue to operate and protect against intrusions from other traffic not monitored by the AILS system. However, this does not preclude an implementation where the AILS system may be incorporated in an expanded version of TCAS, a possibility which is under study.

Appendix A, AILS from the Flight Deck Perspective, provides an overview of the AILS system under development and summarizes the results of some studies at NASA completed to date. Reference 1, comprises the presentations at the NASA workshop on AILS held in October of 1996, and provides details of four NASA studies completed at that time as well as other presentations and discussions from the workshop. Reference 1, includes a discussion describing the paired staggered approach concept by Rocky Stone of United Airlines and Chairman of RTCA SC-186.

Figure 1, presents a generic illustration of the airspace environment in which the parallel approaches will be assumed to be conducted. In much of the discussion to follow, including Figure 1, example values of parameters will be provided, e.g., speeds, altitudes and distances from the runway threshold. It is emphasized that the values provided are examples and that, in an application, the particular values of parameters will need to be determined from the geometry and other constraints of the particular airspace under consideration. As shown in Figure 1, there are three control positions normally involved, the feeder controller, the final controller and the tower local controller. The tower local controller is responsible for the tower traffic pattern and runways. The feeder and final controllers are radar controllers located in the TRACON and are responsible for setting up the approach sequence. The assumption is that traffic is initially under the control of a feeder controller and is handed off to a final controller and then to a tower local controller. A typical approach involves a flight along a downwind leg, a turn to base leg, and then turned to final. The process will also accommodate approaches from other directions in a similar manner by the arrival radar controller vectoring the aircraft into the traffic pattern.

Airborne Information for Lateral Spacing (AILS) is a system for making approaches to closely spaced parallel runways based on flight deck centered technology and accurate flight path management based on use of differential GPS. In the procedure, each equipped aircraft will assume responsibility for accurately managing its flight path along the approach course and maintaining separation from aircraft on a parallel runway. It should be viewed as a system capable of meeting objectives similar to those of the Instrument Landing System Precision

Runway Monitor (ILS PRM) by enabling approaches to closely spaced parallel runways in instrument meteorological conditions (IMC). It is envisioned that the AILS procedure will be described on an approach plate and will require a level of pilot certification to participate in the process. The aircraft will be required to have a minimum set of equipment which may include DGPS navigation capability, a data exchange capability between itself and proximate traffic, and an alerting processor which integrates data received from proximate aircraft with its own state to warn the flight deck crew of collision threats.

2.0 Glossary of Terms and Abbreviations

ADS-B	Automatic Dependent Surveillance Broadcast
AILS	Airborne Information for Lateral Spacing
Airport Acceptance Rate	Sometimes referred to as the “flow rate”, it is a dynamic input parameter specifying the number of arriving aircraft which an airport can accept per hour.
AR	Arrival Radar control position, Feeder and Final
ARC	NASA Ames Research Center
ARTS	Automated Radar Terminal System
ATC	Air Traffic Control
ATCRBS	Air Traffic Control Radar Beacon System
ATCT	Air Traffic Control Tower
ATIS	Automatic Terminal Information Service
Breakout	Used to direct threatened aircraft away from a deviating aircraft.
CC	Cab Coordinator, jargon for coordinator tower position.
CI	Radar Coordinator, jargon for coordinator interphone position.
Close Parallel Runways	Two parallel runways whose centerlines are separated by less than 4300 ft.
DBRITE	Digital Bright Radar Indicator Tower Equipment
DGPS	Differential GPS
EEM	Emergency Escape Maneuver
FAF	Final Approach Fix
FDAD	Full Digital ARTS Display
FM	Final Monitor Controller
FMS	Flight Management System
GPS	Global Positioning System
Handoff	An action taken to transfer the radar identification of an aircraft from one controller to another if the aircraft will enter the receiving controller’s airspace.
IFR	Instrument Flight Rules
ILS	Instrument Landing System
ILS PRM	An Instrument Landing System approach conducted to parallel

Approach	runways whose extended centerlines are separated by less than 4300 ft. and the parallel runways have a Precision Runway Monitor system that permits simultaneous independent ILS approaches.
IMC	Instrument Meteorological Conditions
LaRC	NASA Langley Research Center
LC	Tower Local Control Position
LDA	Localizer type Directional Aid
Level Five Facility	Rating for FAA traffic facilities. Related to the traffic volume the facility is certified to handle. A level 5 facility can handle in excess of 100 aircraft per hour. *(See: Wickens, C., Mavor, A., and McGee, J., eds: Flight to the Future, 1997, pg. 38 for some information on levels.*)
MAP	Missed Approach Point
Missed Approach	A maneuver conducted by a pilot when an instrument approach cannot be completed to a landing.
Mode A/C	The letter or number assigned to a specific pulse spacing of radio signals transmitted or received by ground interrogator or airborne transponder components of the ATCRBS..
MR	AILS Monitor Controller
NAS	National Airspace System
MSP	Minneapolis-St. Paul International Airport
NASA	National Aeronautics and Space Administration
ND	Navigation Display
NM	Nautical Mile
NTZ	No Transgression Zone
Outer Fix	A point along the route of flight normally just prior to entering the TRACON area.
PFD	Primary Flight Display
PPC	Pseudo Position Controller (used in experiment operations)
RTO	Rejected TakeOff
RWY	Runway
s.d.	Standard Deviation
SFO	San Francisco International Airport
SEA	Seattle International Airport

STL	St. Louis/Lambert International Airport
TCAS	Traffic alert and Collision Avoidance System
Tower	A terminal facility that uses air/ground communications, visual signaling, and other devices to provide ATC services to aircraft operating in the vicinity of an airport or on the movement area. Clears aircraft to land and takeoff.
TRACON	Terminal Radar Approach CONtrol. A terminal ATC facility that uses radar and nonradar capabilities to provide approach control services to aircraft arriving, departing, or transiting airspace controlled by the facility. The tower is usually co-located with this facility.
VFR	Visual Flight Rules: Rules that govern the procedures for conducting flight under visual conditions. The term "VFR" is also used in the United States to indicate weather conditions that are equal to or greater than minimum VFR requirements. In addition, it is used by pilots and controllers to indicate type of flight plan.
Visual Approach	An approach conducted on an instrument flight rules (IFR) flight plan that authorizes the pilot to proceed visually and clear of clouds to the airport. The pilot must, at all times, have either the airport or the preceding aircraft in sight. This approach must be authorized and under the control of the appropriate air traffic control facility. Reported weather at the airport must be ceiling at or above 1,000 feet and visibility of 3 miles or greater.
Visual Separation	A means employed by ATC to separate aircraft in terminal areas and en route airspace in the National Airspace System (NAS). There are two ways to effect this separation: a. The tower controller sees the aircraft involved and issues instructions, as necessary, to ensure that the aircraft avoid each other. b. A pilot sees the other aircraft involved and upon instructions from the controller provides his own separation by maneuvering his aircraft as necessary to avoid it. This may involve following another or keeping it in sight until it is no longer a factor.
VMC	Visual Meteorological Conditions - Meteorological conditions expressed in terms of visibility, distance from clouds, and ceiling equal to or better than specified minima.
$\overline{\underline{50}}$	Mandatory altitude, traffic under the control of the referenced position must maintain 5000 feet.
$\overline{50}$	Maximum altitude, traffic under the control of the referenced position must be at or below 5000 feet.
$\underline{50}$	Minimum altitude, traffic under control of the referenced position must be at or above 5000 feet.
$\overline{50}$ $\underline{30}$	Mandatory block altitude, traffic under the control of the referenced position must be between 3000 and 5000 feet.

3.0 Independent Straight-in AILS Approaches to Parallel Runways

The straight-in AILS approaches currently under consideration are to parallel runways spaced at least 2500 ft. apart laterally. Straight-in approaches are frequently characterized by a handoff from the feeder controller to the final controller. Normally, the feeder controller will place the aircraft on a descent into the final controller's airspace. Figure 2, illustrates an example of an AILS approach following a conventional straight-in approach profile. In application, the downwind and base legs may be replaced with an approach profile from other directions, as illustrated in the approach to the right-side runway in Figure 2. A step by step listing of the air traffic controller actions is included in the figure. The numbers along the illustrated flight path correspond to the numbers in the list of actions and are placed in the approximate location along the flight path where the action would probably be completed. It should be noted that this is simply a model which when applied in a particular airspace will need to be adjusted for the particulars of that airspace. The layout of airspace around different airports vary greatly. Some of the actions indicated in the figure are optional.

Current considerations for wake turbulence will permit independent parallel runway approaches to runways laterally spaced no closer than 2500 ft.; however, it is the intent that the process development will be applicable as wake turbulence solutions are found. Therefore, the more general operation will be planned in this examination under the assumption that the resulting process will be applicable to the 2500 ft. runway spacing up to the 4299 ft. case as well as to closer runway spacing where both the independent AILS process and wake turbulence behavior knowledge might be validated in the future. This will obviate the need to establish one set of requirements for runways spaced 2500 ft. or more apart and a second set for runways spaced less than 2500 ft, e.g. 2000 ft. or 1700 ft. It is anticipated that initial applications will be in environments where the runway spacing is 2500 ft. or more.

The AILS process requires the flight deck crew to monitor other traffic by electronic display of data linked information as opposed to direct out of the window viewing. Flight deck crew monitoring of all traffic on the adjacent parallel approach will be required. This protocol more closely resembles close parallel visual approaches when the approach paths are closer than 2500 ft., as it is at San Francisco. Also, the current expectation is that the ATC system will provide the longitudinal separation from traffic operating in the same stream. As one can see, it is not exactly analogous to the visual approach protocol.

To summarize, the AILS protocol will require the flight deck crew to maintain separation from traffic on the adjacent parallel approach and require the ATC facility to be responsible for longitudinal separation of in-trail traffic operating in the same stream.

Another important assumption made defines the point at which the AILS process becomes active and the means by which traffic separation is provided. The AILS system becomes the means for providing safety and separation when the final controller gives the flight the AILS approach clearance. Before that point the final controller is responsible for separation. After accepting the AILS approach clearance, the flight deck crew assumes responsibility for separation. Communications will be switched by the final controller to the tower local controller after the clearance is issued and prior to the final approach fix.

Controller procedures for independent straight-In AILS approaches:

3.1 Inform aircraft that independent straight-in parallel AILS approaches are in use prior to an outer fix, and confirm that the aircraft will be able to conduct that approach. This is normally accomplished using the Automatic Terminal Information System (ATIS).

3.2 Handoff from the feeder controller to the final controller will be conducted prior to the final controller's airspace.

3.3 Final controller will insure that the aircraft's flight path remains within final's delegated airspace.

3.4 Appropriate coordination will be conducted prior to the aircraft entering another controller's airspace.

3.5 The final controller will issue a traffic point out to aircraft prior to turning final.

3.6 Both aircraft will confirm that they have their traffic in sight (under electronic surveillance) prior to being issued approach clearance.

3.7 The final controller will apply standard separation between aircraft during turn-on to final approach.

3.8 The final controller will issue the appropriate AILS approach clearance prior to glide slope interception.

3.9 Both aircraft will assume separation responsibility before losing standard separation.

3.10 In the event of an emergency escape maneuver within the final controllers jurisdiction, the final controller will insure coordination is conducted with the controller of the airspace the aircraft will enter. Subsequent coordination will be the responsibility of the controller whose airspace the aircraft will be leaving.

3.11 Communications transfer to the tower controller frequency shall be completed prior to the final approach fix.

3.12 The tower controller will issue the landing clearance to the aircraft.

3.13 In the event of an emergency escape maneuver while within tower jurisdiction, the tower controller will insure coordination is conducted with the controller of the airspace the aircraft will first enter. Subsequent coordination will be the responsibility of the controller whose airspace the aircraft will be leaving.

3.14 In the event of a missed approach, aircraft shall execute the missed approach as published in the Standard Instrument Approach Procedure.

4.0 Segmented AILS Approaches to Parallel Runways

The segmented AILS approach is illustrated in the approach to the right-side runway in Figure 3. This approach procedure allows aircraft to use flight management system (FMS) capabilities along with DGPS to fly a path that converges to a parallel runway spaced as close as 700 ft. It requires the aircraft to be in VMC and the airport to be in VFR conditions before the minimum certified AILS capability is violated. This means that if the AILS process is approved down to 2500 ft. runway spacing, then by the time the aircraft on the segmented approach comes as close as 2500 ft. from the parallel runway extended centerline, it must have entered VMC conditions and have both the runway and traffic in sight. Basically, the other aspects of the discussion provided for the straight-in AILS approach are applicable in the segmented AILS approach. Handoff of responsibility for separation is made to the flight deck crew when the approach clearance is given.

The question of what procedures will be used as the AILS process is terminated in the vicinity of the 2500 ft. lateral separation from the parallel approach path has been examined. The nominal expectation is that the flights will continue under visual approach protocols after being cleared to land. The condition for clearing an aircraft to land is that the leading aircraft or airport is in sight. An aircraft will have to acquire visual separation from the other traffic prior to reaching the 2500 ft. lateral separation point. The Ad Hoc Team decided to draw on the Localizer type Directional Aid

(LDA) approach experiences of San Francisco (SFO) and St. Louis (STL) airports for guidance since the processes are similar.

Exploring the details of how LDA approaches are conducted at St. Louis airport and how they were managed at San Francisco airport has provided some insight into how this difficulty has been dealt with in similar applications. The bottom line of the St. Louis airport operation is that to the extent possible, the traffic is paired and staggered with one aircraft spaced longitudinal ahead of the traffic on the adjacent runway. In order to receive landing clearance, the trailing aircraft in the pair must confirm to the local controller that the leading aircraft on the adjacent approach is in view and that the runway is in sight prior to the missed approach point. The local controller may provide visual separation as an alternative.

St. Louis airport has an LDA Distance Measuring Equipment (DME) approach authorized to operate in conjunction with simultaneous approaches to the parallel runway. Air traffic control attempts to position the aircraft on the LDA DME approach slightly behind the aircraft making the approach to the other runway. This makes it more efficient and easier for the aircraft to acquire visual contact with the other aircraft prior to the missed approach point, a requirement for this operation (Reference 2). Spacing between the LDA and ILS parallel approach courses is 4,500 feet. Once the aircraft on the LDA approach has the runway and other aircraft in sight it will start maneuvering laterally to the runway, closing the gap between aircraft. The runways are 1,300 feet apart. This operation has increased the flow rate during IMC conditions from 32 arrivals per hour to 52-60 arrivals per hour.

When the LDA was used at SFO, a similar situation was in effect. The aircraft on the offset approach was cleared to land only after entering VMC and confirmation to the controller that the runway and traffic on the straight-in approach was in sight. Note: In both cases heavy jet aircraft were required to use the straight-in approach in lieu of the off set LDA approach. This will be a consideration when managing traffic at SFO using the segmented AILS approach.

In the past, San Francisco International airport used an LDA DME runway 28R approach in conjunction with an ILS runway 28L approach. The aircraft on the ILS approach were set up in a close stagger, 1/2 to 3/4 mile in trail of the aircraft on the LDA approach. This enabled the aircraft on the ILS approach to acquire visual contact with the aircraft on the LDA approach once they entered VMC, a requirement prior to the missed approach point. Prior to the missed approach point, the localizer separation between the two approaches was over 5,000 feet. After the aircraft had visual separation from the other, the aircraft on the LDA was cleared to proceed direct to the runway and land (Reference 3). Distance between runway centerlines is 750 feet. This operation increased the arrival flow while maintaining an efficient departure flow.

Use of the segmented AILS approach will require that aircraft are paired and staggered so that the aircraft on the offset approach path will be expected to see the aircraft on the straight-in path when it enters VMC. The aircraft on the straight-in approach will be positioned ahead of the one on the offset path. Following such a protocol, the flight deck crew on the offset approach, would be required to see the traffic on the straight-in path that has been setup and maintained in the leading position in the pair.

The following outlines the responsibility of the air traffic controllers in the process:

4.1 Inform aircraft that segmented AILS approaches are in use prior to an outer fix, and confirm that the aircraft will be able to conduct this approach. This is normally accomplished using ATIS.

4.2 Handoff from the feeder controller to the final controller will be conducted prior to the final controller's airspace.

4.3 Final controller will insure that the aircraft's flight path remains within final's delegated airspace.

4.4 Appropriate coordination will be conducted prior to the aircraft entering another controller's delegated airspace.

4.5 The final controller will issue a traffic point out to aircraft prior to turning final.

4.6 Both aircraft will confirm that they have their traffic in sight (under electronic surveillance) prior to being issued approach clearance.

4.7 The final controller will apply standard separation between aircraft during turn-on to final approach.

4.8 The final controller will issue the appropriate AILS approach clearance prior to glide slope interception.

4.9 Both aircraft will assume lateral separation responsibility before losing standard separation.

4.10 In the event of an emergency escape maneuver within the final controller's jurisdiction, the final controller will insure coordination is conducted with the controller of the airspace the aircraft will enter. Subsequent coordination will be the responsibility of the controller whose airspace the aircraft will be leaving.

4.11 Communications transfer to the tower controller frequency shall be completed prior to the final approach fix.

4.12 The tower controller will issue the landing clearance to the aircraft.

4.13 In the event of an emergency escape maneuver, while within tower jurisdiction, the tower controller will insure coordination is conducted with the controller of the airspace the aircraft will first enter. Subsequent coordination will be the responsibility of the controller whose airspace the aircraft will be leaving.

4.14 In the event of a missed approach, aircraft shall execute the missed approach as published in the Standard Instrument Approach Procedure (SIAP).

5.0 Paired-Staggered Approaches

The paired-staggered approach paradigm is illustrated in Figure 4. Deliberation on this approach has been deferred for the time being as the Ad Hoc Team addresses the more immediate issues of the straight-in and segmented AILS approaches under consideration for the next simulation studies scheduled for the 1998-99 time frame. This section will be maintained as a place holder for future development.

6.0 The Role of ATC in the Event of an Intrusion Incident

The AILS process as currently envisioned assumes that separation from the aircraft nominally operating in the parallel approach stream will be the responsibility of the flight deck crews participating in the process. The AILS systems and procedures to support the requirements have been developed both to provide flight deck capability to reduce the chance of incursion, and accomplish safe separation from an erring aircraft. No direct involvement by ATC to assume responsibility is expected until the initial conflict has been resolved by the flight deck crews.

Once the initial conflict has been resolved and safe separation achieved, the flight deck crew will expect ATC to assume responsibility for separating the two aircraft involved in the incident from all traffic, and to vector the aircraft back into the approach pattern. The question addressed in this section is: What are the requirements and issues related to the controllers being able to step in at that point and resume responsibility for the safe separation of the deviating aircraft from each other and from other traffic? In analyzing the issues, it is necessary to understand the tasks and responsibilities of the controllers involved, as well as which control positions will likely be impacted.

The deliberations of the Ad Hoc Team on this question have highlighted four issues which will be addressed in detail in the subsections of this topic (Sections 6.1 - 6.4). Sections 6.01 - 6.04 will attempt to clearly state each of the issues.

6.01. Air traffic control tower differences: Towers are organized and operated according to different designs. A single section on how to address the issues in all probability will not be applicable across the board. Some towers split their operations into a north airport and a south airport, for example, with basically separate tower operations for the two sectors. Some will have one tower local controller and one communication frequency for the traffic on the two parallel approaches. Some have a separate local controller and a separate frequency for each of the parallel approaches.

6.02. Number of tower local controllers (LC): How many tower local controllers will be involved in resolving the conflict? This question centers around, whether both approach streams will be on the same tower frequency, or whether there will be two separate frequencies? This also raises a question on how many frequencies will be used in simulation tests. To date, tests at LaRC have assumed separate frequencies? Simulation processes may need to change for the closer-in runway spacing. It may be an important factor to consider that if the two aircraft involved in an intrusion incident are on the same ATC frequency, they may have some warning that an incident is starting. The controller will possibly be urging the erring aircraft back to the final approach course. Hence, this may not be an important issue in the AILS process where the controllers have transferred responsibility for separation to the flight deck crew. Yet, ATC authorities say that it is difficult to imagine that the controller might, viewing his or her traffic display, see an incident evolving and not communicate with the deviating aircraft to attempt to prevent it from crossing into the airspace of the parallel traffic.

6.03. Use of an AILS monitor controller (MR): Related to the above question, in Instrument Landing System Precision Runway Monitor (ILS PRM) applications, as in all current simultaneous independent ILS approach operations, there is a final monitor controller (FM) located in the TRACON, who assures that separation is maintained between traffic on the final approach. The final monitor has override capability on the tower radio communication frequency. Since a final monitor is used in all simultaneous independent ILS approach operations, the central issue of this section is whether a similar position is needed in the AILS operations.

The Ad Hoc Team has concluded that a specially defined AILS monitor controller (MR) could be used in some circumstances. The discussions that follow elaborates on this conclusion.

The basic task of the final monitor, in current simultaneous independent ILS approach operations, is to observe the traffic in the stream being monitored and detect any traffic deviation from its own airspace toward the path of parallel traffic . The final monitor will also intervene if longitudinal separation of traffic within the stream is violated. Specific responsibility will be defined for the terminal area under consideration and vary from terminal area to terminal area. In any event, the responsibility for managing traffic ahead of, and behind, the traffic involved in the incident continues for the LC. In some busy environments the workload of the local controller will be too high to expect that position to absorb the additional responsibility of managing the deviating aircraft. In the worst case, the aircraft which initially caused the incident may have a radio communication problem. In all cases where there is a tower emergency, it is expected that the local controller will need help.

One scenario under consideration is that the aircraft on the parallel approaches are all on a single tower frequency with a single local controller. This is the type of operation that is envisioned in an environment such as SFO. The single local controller will be responsible for both aircraft should an intrusion incident occur. Also, that controller may have to coordinate with appropriate adjacent airspace controllers. The issue is, that it is quite possible that the workload of the single local controller can easily get too high for that controller, and assistance in managing an emergency by a special AILS monitor would be required in such a case. This examination, however, must recognize the role of the tower cab coordinator (CC) in the process.

6.04 <u>Requirements for controllers to accept responsibility for separation</u>: One of the premises of the AILS process is that the controller will have no effective way to manage conflicts in the closely spaced parallel runway environment. Responsibility for separation from traffic nominally on a parallel approach path will be handed off to the flight deck crew as in visual approaches. When an emergency escape maneuver is executed to avoid a collision threat, the controller will be contacted at some point. The flight deck crews involved will expect the controller to accept responsibility for separation from other traffic. The issue is, what are the requirements that need to be met to enable controllers to accept the responsibility for separation? One concern is that the DBRITE and Full Digital ARTS Display (FDAD) and the radar systems that support them do have limits on their resolution. A central question is, when can the controller, using the radar display, adequately determine the position of the two aircraft? Only at that point can the controller accept responsibility for their safe separation and vector them back into the traffic pattern.

The following paragraphs will address the issues raised in Sections 6.01 - 6.04 respectively. An important point to be made in the discussions of this report from the Ad Hoc Team is that, although there are some generic issues which can be addressed, any AILS solution will need to be tailored to the conditions of a particular terminal area. Those details will probably make the solution unique to that particular application. This point will be made more clear as the recommendations for experiments for the three terminal areas, Seattle-Tacoma (SEA), San Francisco (SFO), and Minneapolis-St. Paul (MSP), are discussed in Section 8.0 of this document.

6.1 Operations vary Significantly from Airport to Airport

As the AILS program is evolving, and partnerships with interested potential customers for the technology are forming, airports that are of particular interest are being identified. Initially, the airports of interest are assumed to be Seattle-Tacoma, San Francisco and Minneapolis-St. Paul.

The Seattle-Tacoma airport environment was selected because there is an existing construction project to complete a parallel runway spaced 2500 ft. from an existing runway. Operating independent parallel AILS approaches to that pair could potentially be of benefit to the Seattle-Tacoma airport operations. Also, the initial target closest approach for application of independent AILS approaches is 2500 ft., a limit based on wake turbulence considerations. From the vantage point of the Ad Hoc Team, SEA is the optimal selection for studying such an application.

The San Francisco airport environment was selected because it was the model terminal area where the initially proposed AILS experiment was designed. It was the initial plan to study application of a segmented approach in that terminal environment. Inasmuch as that plan was still under consideration in the AILS Team deliberations as this report was being prepared, the Ad Hoc Team concluded that it would be appropriate to develop a plan using that terminal area model.

The Minneapolis-St. Paul airport environment was selected because the ILS PRM system is currently in use there. Eventual testing of the AILS process in such an environment where there is a proven system (to backup the process in a live test environment) might be an attractive opportunity.

Table1 presents a listing of the airports thought to be candidates for AILS technology applications. The information in the table is intended to aid in understanding the differences in the operations at the airports under consideration as they relate to considering the role of air traffic controllers in the AILS process. The Ad Hoc Team has prepared a separate document, Reference 4 (Doyle and McGee), to compile information on airports that have parallel runway pairs. The information contained in Reference 4 includes measures of the amount of traffic operating at the airport and how the parallel runway pairs are used. The central issue of this topic is the following: If the controller is involved in dealing with an intrusion incident, will the resources be available to safely meet the requirements? Depending on the position description of the tower local controller, study of the role in completing the resolution of an incident in one terminal area may not be applicable to the solution in another terminal environment. A primary factor seems to be the degree of loading (in the task load sense) of the local controller.

In Table 1, the number of local controllers is listed as one of the entries. Although it is good information to have, it has to be thought of in view of what the responsibilities of the local controller are. An example to make this point is in the consideration of San Francisco air traffic control tower and Portland air traffic control tower. They both have a single local control position; that LC is responsible for departure and arrival traffic to all runways. The issue for Portland tower is that traffic volume and flow management require only one LC. On the other hand, at San Francisco tower the issue is that the coordination of traffic on the two sets of parallel runways, and the queuing of arrival and departure traffic, is so critical that use of two LC's is regarded as presenting significant coordination problems and raising safety issues.

Table 1. - Tower Operations at Select Airports with Close Parallel Runways

Airport	Rwy Pair	Parallel Rwy Spacing	No. of Tower Local positions	Comments (Tower Operation)
Ft. Lauderdale	9L/R	4000	2	Low traffic volume
Detroit	21R/C	3800	3	RWY 21C used for departures
Salt Lake City	16L-17	3700	3	Primary operations on RWY 16L/R
Phoenix	26L/R	3565	2	Low visibility unusual
Raleigh	23L/R	3400	2	Low traffic volume
Memphis	36L/C	3400	3	RWY 36C used for departures
Minn.-St. Paul	30L/R	3380	2	ILS PRM Approaches RWY 30L/R
Portland	10L/R	3100	1	Low traffic volume
Kennedy	4L/R	3000	2	Primary operations on RWY 31L/R
Detroit	21L/C	2000	3	RWY 21C used for departures
Orlando	18L/R	1500	2	RWY 18L used for departures
Boston	4L/R	1500	3	1 LC Helicopter Position
Philadelphia	27L/R	1400	2	RWY 27R used for departures
St. Louis	30L/R	1300	3	LDA Approaches RWY 30L
Dallas-Ft. Worth	17C/R	1200	2	RWY 17R used for departures
Dallas-Ft. Worth	18L/R	1200	2	RWY 18L used for departures
Pittsburgh	28C/L	1200	3	RWY 28C used for departures
Atlanta	26L/R	1000	2	RWY 26L used for departures
Atlanta	27L/R	1000	2	RWY 27R used for departures
Houston	14L/R	1000	3	Primary RWYs 26/27. GA use RWY 14R
Las Vegas	25L/R	1000	2	Low visibility unusual
Oakland	27L/R	1000	3	RWY 29 used for departures
San Francisco	28L/R	750	1	1 LC for all 4 RWYs. One set of RWYs used
San Francisco	1L/R	750	1	for departures other set used for arrivals

6.2 Tower Operation Procedures and Number of Local Controllers

This discussion has significant overlap with the discussion of the differences in airport traffic areas in Section 6.1 above. The primary issue in the current section is to acquire an appreciation of how the towers are operated in terms of staffing and task assignments. This varies from airport to airport and depends on factors such as traffic volume, air space constraints, and complexity of the operation, for example, large difference in types of aircraft operating at the airport.

The tower operation should be viewed as a team of controllers conducting the tasks necessary to guide and manage traffic landing at and departing from the airport. There will normally be a supervisor who is responsible for overall operation of the facility. The supervisor will be present in the tower and will get directly involved in the resolution of any emergency. Clearly, from the tower operation vantage point, an aircraft crossing into the path of another, posing a collision threat, should be treated as an emergency. All available hands come to the aid of the local controller to assist in resolving the problem.
Secondly, there is a position commonly referred to as the cab coordinator. The cab coordinator operates in the tower cab and is responsible for providing proper coordination between the tower controller positions and the radar coordinator who has a similar responsibility in the TRACON. Normally, the job of the cab coordinator is to maintain an overall perspective of the traffic in the tower pattern and provide necessary coordination between the controllers. In an emergency, this position will get directly involved and offer assistance to the local controller in resolving a problem, including coordinating both among the tower positions, and with the positions in the TRACON including the radar coordinator (CI). The tower coordinator (CC) will normally inform the CI about the deviating aircraft (although the TRACON controllers will likely have already detected it on their radar displays). The CI and CC will coordinate a planned route and handoff of the deviation aircraft to the appropriate TRACON positions.

Typically, there will be one, two, or three local control positions in a tower. Their responsibilities can be divided in a number of ways when there is more than one depending on the facility plan. Usually one controller is responsible for traffic operating on or making an approach to one of the parallel runways, and a second LC position is responsible for traffic approaching or operating on the other. The third controller may be responsible for traffic on a third runway.

The number of local controllers involved in the traffic conflict and its resolution has a significant impact on the event. This factor needs to be considered in addressing the issue of the role of the local controller in resolving conflicts. Two local controllers working the problem will require coordination, but might lessen the workload compared to the same problem managed by one controller. Table 1 provides a list of the selected airports with close parallel runways and includes an entry presenting the number of local control positions in the tower at these airports.

6.3 Use of an AILS Monitor Controller

In considering the ATC activities when an intrusion incident occurs, a point that needs clarification is the question of whether there is a need for a final monitor controller or a similar position tailored to the AILS process. Whenever there is a simultaneous independent ILS approach operation closer than 3 NM (virtually all), a final monitor position is required. The job of the final monitor is to observe the parallel traffic and assume primary responsibility for resolving intrusion threats and incidents. That position has the priority override on the tower local control communication frequency. The final monitor position is located in the radar room of the TRACON, not in the tower.

The following are the points which appear to be factors in making a decision regarding the use of a monitor position in the AILS process:

With Final Monitor Position	**No Final Monitor Position**
1. Relieves tower workload	1. Higher workload for tower in incident
2. High safety	2. LC workload could raise safety questions
3. Increased frequency congestion	3. No frequency override by FM position
4. Increased staffing requirements	4. Lower staffing requirement
5 Increased equipment and maintenance	5. Less equipment and maintenance
6. Possibly necessary for SFO where tower controller handles departures	6. Probably applicable where two tower local controller position environments exist
7. AILS monitor task definition different from existing FM's · No monitoring task - No NTZ · AILS alerts on the ground side · Participates in incident resolution only.	7. Local controller resolves the incident

There are some related points to consider in addressing the issue of whether a monitor controller is needed in an AILS application. Sections 6.3.1- 6.3.3 along with their subsections address some of these points.

6.3.1. Longitudinal Separation Responsibility Issue

The issue of responsibility for longitudinal separation between aircraft on approach in the same stream during an AILS operations has been highlighted. Should this be an ATC function or a flight deck function? The Ad Hoc Team has concluded that it should be an ATC function in the AILS process. The rationale for this conclusion is presented in the following paragraphs:

6.3.1.1 It has been pointed out that in the monitor controller environment, used for virtually all simultaneous independent ILS approaches, the monitor controller in many cases has the responsibility for longitudinal separation once the traffic is switched to the tower local controller frequency. The monitor controller (or local control, depending on the protocols of the particular terminal area) can give speed adjustments to aircraft operating in the flow, up to the final approach fix (FAF). Inside the FAF, the monitor controller (or local controller) can advise the aircraft of the speed causing a separation problem but may not issue speed adjustment instructions. If violation of separation standards appears imminent, the monitor controller (or local controller) has the option to issue missed approach instructions to the problematic aircraft. Some of the details are options of the particular terminal area, for example, whether the local controller or the monitor controller will be responsible for longitudinal separation.

6.3.1.2. A question of whether the flight deck crew can accept the responsibility for longitudinal separation from leading traffic in the same stream is raised. How can this be accomplished? Should there be specialized displays and alerts to support this task requirement? Reference 5 (T. Abbott) may be of interest in providing flight deck aids to conduct such a task. The bottom line is that the current AILS process does not include procedures and equipment to support the flight deck crew in maintaining longitudinal separation. On the surface, this does not appear to be an unsolvable problem; however, a method has not been developed and validated to date.

From the ATC vantage point, the following is an issue: In current IFR operations when ATC is directly responsible for separation during the entire approach, the requirement is that traffic be maintained at standard separation, which includes a minimum 3 NM miles in-plane or 1000 ft. altitude separation. Actual in-plane minimum separation requirements depends upon aircraft types involved and wake turbulence separation standards. If the standard separation is violated then a reportable incident has occurred and disciplinary action may be taken against the controller. As pointed out earlier, the monitor controller assures that separation standards are maintained by applying various control techniques to traffic prior to any loss of separation.

In recognizing the issues discussed above, the ad hoc team recommends use of an AILS monitor in some terminal environments. The role of the AILS monitor will be defined differently from that of the monitor controller, but will include responsibility for assuring longitudinal separation of same stream traffic. This recommendation is related to a later recommendation that ATC will be responsible for longitudinal separation of aircraft from other traffic within a given stream.

6.3.2 The Issues of Maintaining Controller Responsibility for Longitudinal Separation

The question under consideration in this section is the following: In an AILS environment can controllers maintain responsibility for longitudinal separation of traffic in the same stream, while responsibility for separation between traffic operating in a parallel stream is handed off to the flight deck crews involved? Some of the considerations are the following:

6.3.2.1 For independent straight-in approaches, longitudinal separation of traffic in a given stream is independent of the separation from traffic operating on an adjacent runway. However, for segmented AILS approaches the problem is more complicated. At SFO traffic is expected to be paired and staggered, consequently not independent of the other stream.

6.3.2.2 The longitudinal spacing between aircraft in a given stream will largely be dependent on the approach speeds of successive aircraft in the same stream. Spacing will be managed by a controller using speed control (for example, “maintain one seven zero knots to the FAF”). Once inside the FAF, aircraft will adjust to their final approach speed, which is different for various aircraft. The controller has to be aware of these speed adjustments by the aircraft inside the FAF and advise the flight deck crew if their aircraft is overtaking the leading aircraft in the same stream. There will be no requirements to consider any impact of the adjacent runway operations. At most airports there will be one controller managing a single runway stream of traffic. No additional workload above what the controller is normally use to is implied.

6.3.2.3 With the above details in mind, there appears to be no additional workload for the controller responsible for a single stream of traffic, to maintain responsibility for longitudinal spacing between aircraft on final approach. San Francisco airport is recognized as an exception since a single controller is responsible for traffic in the two parallel streams during VFR conditions.

6.3.2.4 A plausible paradigm is that responsibility for separation between traffic operating on adjacent runways can be handed off to the flight deck crew as in visual approaches, but responsibility for separation between traffic in a given longitudinal stream can be maintained by the air traffic controllers. If there is a longitudinal in- trail threat or violation, the air traffic controller will manage it. If there is a lateral threat or violation the flight deck crew with AILS system will be required to manage it. There will be no longitudinal constraint between aircraft operating in adjacent streams. This last statement may not be a pure condition and some related issues will be raised later. These issues relate to requirements to pair aircraft in the streams to make holes to facilitate departures. The pairing and staggering also has an additional benefit which needs to be understood as the AILS process is tailored for particular terminal areas.

6.3.2.5 The goal of the AILS research is to enable approaches to closely spaced runways in IMC with a capacity similar to that obtained in VMC. The proposed methodology requiring ATC management of longitudinal separation of traffic in stream gives up any single stream capacity gains normally realized in a VFR operation over the capacity of an IFR operation of a single stream. The longitudinal spacing provided by ATC will be according to current longitudinal spacing standards based on wake turbulence considerations. The gain realized will come from the use of both closely spaced parallel runways during IFR conditions.

6.3.2.6 The recommendation of the Ad Hoc Team for the SFO situation, where a single local controller is responsible for the traffic on the approach to two runways is the following: A specially defined AILS monitor position, similar to the final monitor position, whose responsibility will include assuring the longitudinal spacing of aircraft on the approach could be used. As mentioned earlier, the longitudinal spacing task is frequently the responsibility of monitor controllers in parallel runway operations. This requirement to leave the longitudinal spacing between aircraft in a stream as an ATC responsibility adds additional weight to the argument that an AILS monitor will be required for AILS operations in SFO. Whether the AILS monitor may be recommended for use in other proposed AILS applications will be determined by examination of the details of the particular airport operation. Note: At SFO the arrival-final controller sets traffic up on final with 5 miles between aircraft during VFR or IFR conditions to accommodate departures.

6.3.3 Issues Related to Transferring the Responsibility for Same Stream Spacing to the Flight Deck Crew

One possibility that was considered by the Ad Hoc Team is that the flight deck crew will be responsible for longitudinal separation from traffic in the same-stream, this is the protocol followed in visual approaches. The Ad Hoc Team has decided against making this a recommendation, in favor of the ATC system having the responsibility. However, it is appropriate to document the points which surfaced in the deliberations.

The question under this alternate paradigm is whether the flight deck crew can perform this task in addition to the other requirements of the approach operation in an AILS environment. The following are some of the considerations:

6.3.3.1. In current VFR close parallel runway operations, the flight deck crew will have the responsibility to manage longitudinal spacing behind leading aircraft visually through out of the window viewing. The discretionary latitude that the flight deck crew takes in this process usually increases the runway capacity in a given stream because the pilots are generally less conservative in their spacing than the wake-turbulence based standards used by ATC. Pilots also, having their traffic in view, use other techniques to avoid wake turbulence from aircraft they are following. For example, they will fly above the path of leading aircraft.

6.3.3.2. The present AILS research display formats do not allow an adequate viewing distance ahead to continuously see the leading aircraft if the display range selections currently advocated for AILS monitoring of traffic on adjacent runways is utilized. In operations at LaRC where 2500 ft. laterally spaced parallel runways have been studied, two display ranges were used, a 2 NM range and a 10 NM range. These ranges represent the total field of view of the display from the bottom edge of the map and traffic display to its top edge (or equivalently, from the left edge of the display screen to its right edge). A significant outcome of the experiment was that performance in the emergency escape maneuver (EEM) was not dependent on the display range or scale factor used when these two values were tested. However, the pilots who were the subjects of the tests indicated a significant preference for the 2 NM display format where they could resolve relevant lateral displacement of traffic on the parallel approach. The AILS Team has continued to pursue use of the higher resolution, low field of view display formats. This format offers the advantage of displaying information to support determining how well the emergency escape maneuver is working and to make timely adjustments where appropriate. It does not support the viewing of traffic in the longitudinal stream.

6.3.3.3. Giving the flight deck crew the responsibility to manage the longitudinal spacing will require that procedures and tools to manage that spacing be provided. Viewing the traffic on a map display presented along with the parallel traffic presents a dilemma. The requirement to monitor the adjacent traffic demands a display which will allow resolution of significant deviations (250 ft., best approximation) from a 2500 ft. displaced extended runway center line. This information is displayed on a 6 1/4 inch by 6 1/4 inch viewing screen roughly 30 inches from the pilots eyes. The 10 NM scaling used in some of the AILS testing translates to 1.6 NM/inch, which implies the 250 ft. on the display will be represented by 0.026 inches on the display. One thousand feet is equivalent to 1/10 inch. This display format does not support modifying and adjusting evasion actions to assure separation in close operations. It will support viewing of leading traffic five to seven miles ahead of the own aircraft. The 2 NM display format, favored in the AILS testing, will provide 5 times the display resolution, representing 250 ft. as 0.11 inches. However, it will not allow viewing traffic more than about a mile and a half ahead.

6.3.3.4. The Ad Hoc Team recommends that the responsibility for separation from traffic on the parallel approach should be given to the flight deck crew. Responsibility for in-trail separation in a given longitudinal stream should be an ATC function in the AILS process.

6.4 Requirements of the Controller to Resume Responsibility for Separation

It is not a trivial matter for the controller to accept control of the aircraft and responsibility for separation at any point in time that the flight deck crew requests ATC control and vectoring. This would become apparent after an emergency escape maneuver, and when the controller could legitimately accept responsibility for separation of the aircraft involved. The controller must have the resources to resume control of the situation. ATC must be ready to accept the additional workload, and have an adequate view of the situation to make safe and accurate decisions. What are the requirements? Controller display resolution, and aircraft position and heading are key considerations.

A primary consideration is that when the controller is requested to accept responsibility for separation, the appropriate tools must be available to support execution of the necessary tasks. Specifically, the radar display used by the controller should allow clear resolution of the aircraft which are to be controlled. The rule of thumb used by controllers is “green between and diverging.” In other words, since the background color of the Full Digital ARTS Display (FDAD) is green, a controller will see that color between targets that are not merged. Also the targets should be moving apart on diverging courses where standard separation can be more readily applied.

A factor related to this question is the actual resolution capability of the radar equipment. The measurement accuracy of the ARTS and Air Traffic Control Radar Beacon System (ATCRBS) was determined in Reference 6. The information presented below is based on the information provided there. The following table summarizes the data present.

Table of Surveillance Performance

	ARTS		SSR Mode of Mode S	
	ALL	Crossing	ALL	Crossing
Blip/scan	94.6 %	86.9 %	98.0 %	96.6%
No altitude	2.7 %	8.3 %	1.4 %	3.0 %
No code	1.5 %	7.4 %	0.7 %	3.0 %
Range error (1 s.d.)	124 ft.		24 ft.	
Azimuth error (1 s.d.)	0.16 deg		0.4 deg	

Blip/Scan Ratio - the probability of generating a target report during one scan.

No Altitude - the percentage of Mode C reports that did not contain a valid altitude.

No Code - the percentage of Mode A reports that did not contain a valid code.

Range Error - the standard deviation from a second order polynomial fit to a sliding sequence of range measurement points, centered on the report being evaluated. The error is calculated only for established straight-line tracks at elevation angles between 0.5 and 40 degrees and at ranges between 2 and 45 NM.

Azimuth Error - same as range error, but in the azimuth dimension.

Based on this information it is not intuitively obvious why the selection of one-half-mile-wide target sizes are used. One thought is that there are other factors which may contribute to the total error that must be taken into consideration. (Discussion to be completed.)

Figure 10 illustrates the appearance of symbols on the controller’s display. As the figure indicates, the width of the target covers a one-half mile area of the display. This scaled size of the aircraft symbols is maintained as the selected display scaling is changed. Figure 11 illustrates a number of possible display conditions of two target aircraft operating in close proximity and illustrates some situations where they may not be judged acceptable for the controller to assume separation responsibility. If there is not the 1000 ft. altitude separation indicated in the targets data tag information or the targets are touching or not diverging, the controller is required to advise the aircraft requesting instructions that the targets are merged. The controller can not accept responsibility or issue instructions in that situation at least until there is resolution between the targets.

The AILS procedures and supporting avionics in the flight deck should provide enough information to the pilot of the evading aircraft to gain appropriate separation from traffic to permit the controller to assume ATC responsibility. The information necessary to generate a visual or aural signal in the flight deck is the same as that which the AILS algorithms use to generate a traffic alert.

7.0 Display and Alerting Information for the Controller

7.1 Displays: The format of information presented must be such that the controller can visually see separation between the aircraft when required to vector the aircraft unless there is altitude separation. If altitude separation is less than 1000 ft. and the two aircraft symbols involved in an encounter are overlapping on the controller’s display, it will not be possible to safely vector them. The normal display at the tower local controller position is the Digital Bright Radar Tower Equipment (DBRITE). ARTS IIIA / IIIE and radar equipment provide the measurements necessary to display location of the target aircraft. The aircraft symbol size in DBRITE presentations are 1/2 NM (scaled), Figure 10. This implies that the visual capability of the controller in viewing two aircraft on the presentation is bounded by the parameters of these systems. The information available indicates that local controllers frequently use the 15 NM range selection on their DBRITE. However, this is a user preference issue and other range selections, from the available choices (10 to 40 NM increments of 2 NM) can be selected by the user where necessary or desirable.

7.2 Alerts: The controller should be alerted when an intruder alert is issued to an aircraft operating in the airspace of that position. If there is an AILS monitor, the AILS monitor should also be alerted as well as the local controller and the final controller. The mechanisms by which the alerts could be issued are:

- The crew of the evading aircraft informs the controller via voice radio.

- ADS-B or other data link transmits information bits from the aircraft to the ground when a flight deck alert is issued.

- Ground equipment independently computes alerting algorithm using ADS-B information from aircraft.

(Initial comments have suggested that each of these be implemented)

At the time of this reporting the specifics of this alerting process have not been explored in any detail.

8.0 Suggested AILS ATC Simulation Experiments

In this section the Ad Hoc Team has attempted to design experiments that could be conducted using approaches in airspace models of three different terminal areas. The three terminals selected are Seattle-Tacoma, San Francisco, and Minneapolis-St. Paul. The reasons for these selections are briefly stated in Section 6.1. The actual experiment definitions are presented in this document's appendixes in significant detail. One of the hopes of the Ad Hoc Team in developing these three example experiments is that the process and discussions will highlight the significance of the particular features of the terminal area in shaping the format of an AILS application.

8.1 Straight-in AILS Approaches in a Seattle-Tacoma Terminal Airspace Model

Appendix E presents an experiment plan for a simulation test of straight-in AILS approaches in a model of the Seattle-Tacoma terminal area. A full discussion of the assumptions and experiment plan is provided. The discussion includes a subjective evaluation form to be used by the controller test subjects. It also includes test incident scenarios to be used in the study. These scenarios assume that the intrusion incident would be staged using pre-recorded data as in previous AILS simulation experiments, and that final resolution of the incident by the controllers will involve issuing instructions to guide the flights along routes described in the incident scenarios, once separation responsibility is accepted. The designed scenarios include the assumption that the flights will continue two to three minutes beyond the start of the intrusion incident, until the erring aircraft are integrated back into the traffic flow streams.

Figure 12 illustrates the assumed nominal traffic flow pattern in the SEA terminal area. Figures 13 through 16 present four suggested incident scenarios for use in the tests.

8.2 Segmented AILS Approaches in a San Francisco Terminal Airspace Model

Appendix F presents a plan for simulation testing of the AILS process in a model of the San Francisco terminal area. Suggested scenario details are also included. Figure 17 shows the general traffic flow pattern assumed for the SFO terminal area using a segmented AILS approach. Figures 18 through 23 illustrate suggested incident scenarios for use with that traffic model.

This is the terminal area for which a segmented AILS approach is being considered. The parallel runway pair, 28L and 28R are laterally spaced 750 ft. apart. In a VFR operation where both runways are used for simultaneous approaches, the aircraft on the two runways are paired and the flight crews are cleared to make visual approaches. The reason for the pairing is that at least a 5 NM gap is needed between landings on the runways to allow departures on the two runways 1L and 1R which cross the 28L/28R pair at 90 degree angles. Therefore, a pair of aircraft will land approximately simultaneously on runways 28L and 28R, then during the gap, aircraft will be released to depart on runways 1L and 1R. Then, the next pair will land on runways 28L and 28R. The attempt is to keep the paired traffic together to make the process efficient.

Because there is an issue of meeting requirements for visual approaches when the AILS portion of the segmented approach is ended, the Ad Hoc Team recommends that the traffic be paired and staggered for the segmented AILS approach. Pairing will also be needed to achieve efficiency in managing the departures. The intent will be to maintain the aircraft on the segmented AILS approach in a relative position behind the aircraft on the straight-in AILS approach path so that the leading aircraft will be in the forward field of view of the crew of the trailing aircraft when the trailing aircraft enters visual conditions. This will facilitate visual acquisition of the traffic on the straight-in AILS approach. The requirement for the trailing crew to continue on the approach as its lateral spacing from the adjacent approach path closes to less than 2500 ft., will be for the crew on the segmented AILS approach to see the traffic on the adjacent approach. And, to maintain visual separation from that traffic prior to the missed approach point (MAP), which would be the point where there is 2500 ft. separation between runway centerlines. Note: Heavy jet traffic may be required to use the straight-in approach procedure only.

8.3 Straight-in AILS Approaches in a Minneapolis-St. Paul Terminal Airspace Model

Appendix G presents a plan for testing of the AILS process in a model of the Minneapolis-St. Paul terminal area. The traffic flow pattern assumed for the MSP terminal area is illustrated in Figure 24. Suggested scenarios are also included for the test. A significant feature of this plan is that it is patterned after the ILS PRM process currently in use at MSP and does not represent a purely independent parallel approach process. In order to manage the departure traffic the controllers generally pair the traffic on the approaches to the two runways. This is not a requirement, although, it is the normal practice apparently because it is a more efficient procedure. The final controllers create a gap of at least 5 NM on both of the parallel runways.

In summary, the traffic flow pattern is normally maintained by landing two aircraft on the parallel runways, then allowing departures on the same two runways. According to air traffic management at MSP, this is currently the way the ILS approaches are managed at MSP when the parallel runways are used with the PRM system. It is emphasized that the pairing of traffic is not a requirement.

An additional factor helps to understand why that pairing is done. When the traffic volume is lower, PRM is not required, dependent approaches are used. In that event, the two aircraft are staggered according to separation standards. Maintaining the aircraft in pairs facilitates setting up the stagger in the dependent streams. Having them paired in both the dependent operations and the ILS PRM operation facilitates transitions between the two modes of operation. The controllers set up the pairs in the feeder and final airspace and either stagger one longitudinally behind the other (dependent operations) or allow them to continue in pairs during the ILS PRM operation Note: The approaches at MSP are "simultaneous independent ILS PRM approaches".

An important aspect of the above discussion is to provide credibility to the concept of using pairing and staggering in the AILS segmented approach concept. This information is highlighted here along with the descriptions given of the pairing and staggering used in LDA operations currently in use at St. Louis airport, and formerly used at San Francisco airport. These existing applications form the basis for justifying the recommendations of the Ad Hoc Team to use pairing and staggering in the segmented AILS approach concept.

9.0 Recommendations for the ATC Operations in the Planned Simulation Study

Appendix B presents a table that summarizes the deliberation of the Ad Hoc Team related to conducting a simulation study of the ATC process. The table details experiment objectives including different levels of simulation, cost and time factors, and facilities that may be capable of conducting the planned simulation. The table also depicts expected benefits derived from the simulation, a relative rating of the simulation objectives, and pertinent comments with a numerical recommendations of the simulation levels deemed to have the most realistic chance of success considering cost and time.

The first simulation level, row one, represents a complete full up simulation with all relevant positions staffed by qualified air traffic controllers. The positions listed for the full up simulation in the first row, column one are feeder controller, final controller, tower local controller (LC), tower coordinator (CC), and TRACON coordinator (CI). Column two presents an estimate of the number of personnel directly participating in the simulation and a rating of the relative cost factor. As shown in row one, column two, the “high” entry reflects the Ad Hoc Team’s belief that this would be a very costly way to conduct the experiment. The time factor represents how long it is going to take to prepare and conduct the experiment at that particular level. Column three lists known facilities that may have the capability of conducting that simulation. The Ad Hoc Team analyzed the benefits that may be derived from each level of simulation and assigned a relative rating to each one.

Experiment objectives, one through seven are listed at the bottom of the table for reference. The columns titled “objectives” labeled with numbers one through seven, refer to these objectives respectively. The entries in these columns are an estimate of the contribution toward meeting these objectives for the simulation level in the particular row. The last column gives pertinent comments and, where applicable, the Ad Hoc Team’s ordered choice of the various levels of simulation. The choices, one through five and a fall back position, represent the Ad Hoc Team’s assessment of the most practical and realistic level of simulation that will provide measurable data. The fifth choice and fall back choice would not involve qualified air traffic controllers, only pseudo controllers. The first choice is simulation level four. The view of the Ad Hoc Team was that this choice would provide data on the critical controller positions in the process while providing a realistic simulation environment in support of the flight deck experiment. The simulation requires two tower local controllers and a TRACON final controller. All the other controller positions will be simulated through software or by a pseudo controller. The Ad Hoc Team expects all objectives of the experiment can be fully realized by using this level of simulation. The second through fourth choices represent experiment options with fewer positions fully simulated, and therefore provide lower benefits than the first choice. Clearly, less resources will be required to conduct the experiment in these modes. The fifth choice and the fall back choice would adequately support the flight deck simulation but would not provide any ATC process evaluation.

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Appendix A

10.0 AILS from The Flight Deck Perspective

Airborne Information for Lateral Spacing is an effort within the Reduced Spacing Operations (RSO) element of the Terminal Area Productivity (TAP) program at NASA.
The objective of the AILS research being conducted at the Langley Research Center (LaRC) and at the Ames Research Center (ARC) is to enable approaches to closely spaced parallel runways in IMC with a capacity similar to that obtained in VMC. This research is examining options to enable airborne flight deck crew responsibility for aircraft separation during closely spaced parallel approaches. The initial focus of the NASA work has been on independent parallel approaches with intentions of investigating segmented and paired staggered approach concepts as time and resources permit.

LaRC and ARC have planned a number of studies to address the problem, with LaRC taking the lead in this activity. A concept design team has been assembled to address the problem. The team at LaRC has designed an initial concept after concluding that the problem of flying parallel approaches has two major components. The first is to provide accurate navigation for aircraft on the closely spaced parallel approach paths and to provide alerts to help keep intrusions from occurring. The second is to provide adequate protection for aircraft should one aircraft deviate from its assigned airspace in a manner that threatens another aircraft on a parallel approach path. The research at ARC has focused on providing TCAS like display guidance during collision avoidance maneuvers. The AILS work to date has addressed parallel pairs as opposed to parallel triplets or quadruplets, since it presents a simpler, yet real problem with significant payoff potentials.

Figure 5 illustrates technology that could potentially be used to implement the concept. DGPS provides the basis for the accurate navigation required to perform the approach, while ADS-B, currently under development, will enable aircraft to broadcast their position and other state information such as track, and rate of turn. Other aircraft will receive the transmitted information and maintain an accurate fix on aircraft operating on a parallel approach. In addition, the transmitted state information will provide an indication of whether the traffic is turning away from its course or headed back to its nominal path.

As mentioned above, the AILS concept focuses on two aspects of the problem. One aspect is to provide accurate navigation to keep aircraft in their own assigned airspace along the approach paths and keep aircraft from threatening others. LaRC engineers are investigating whether the conventional localizer path can be replaced (in AILS applications) with capabilities such as DGPS to provide parallel approaches where there is less potential for path overlap. Figure 6 illustrates the modified localizer path designed for use in AILS approaches. In the area of “localizer” capture, the two dot deviation is 2000 ft. on either side of the extended runway centerline. Also, as is normal for parallel runway operations, the approach paths are separated by 1000 ft. altitude during localizer capture. At about 12 miles from the runway threshold, the path width begins to taper down to 400 or 500 ft. (depending on the application) on either side of the extended runway centerline at 10 miles. After the 500 ft. half-width area is entered, the higher aircraft starts to descend and altitude separation is given up. The 500 ft. half width of the path is held from that point to a location near the middle marker where a conventional localizer angular beam shape and width are captured (using DGPS to emulate the conventional localizer signal).

An alerting feature has also been incorporated in the concept to prevent aircraft from straying from their airspace. Figure 7 shows the primary flight display (PFD) and the navigation display (ND) used in the simulation testing completed at LaRC as they appear during nominal AILS approaches. The AILS related information is labeled. Should an (own) aircraft deviate one dot or more from its nominal path, a caution or level two (SAE ARP-450D) alert is issued to the deviating aircraft with displayed information presented in amber alphanumeric and symbolic formats (Figure 8) in the primary flight display and in the navigation display, to warn the flight deck crew to maintain a tighter path adherence. Should an aircraft deviate two dots or more from the prescribed path, a level three alert is issued (using red colors for the displayed information), requiring an emergency escape maneuver (EEM) in the direction away from the parallel traffic. In the version of the LaRC concept implemented for the second phase of testing, depending on the severity of the situation, level two or level three alerts are also used to prevent one aircraft from threatening another with excessive bank angles or tracks. The current LaRC concept requires use of a single, identical EEM for all parallel approach deviations. The aircraft required to abandon the approach must execute an emergency escape maneuver consisting of a turning climb to a heading 45 degrees away from the nominal runway heading, in the direction away from the parallel approach traffic. A heading bug is automatically set to the (45 degree) escape heading when the alerting algorithms are armed in the approach sequence. Note: The degree of turn may have to be modified in the case of segmented approaches.

The second aspect of the LaRC version of the AILS concept addresses procedures to avoid collisions and near misses in the event one aircraft strays from its airspace and approaches the path of another in a threatening manner. An onboard alerting algorithm will use state information from traffic on the parallel runway, transmitted by the ADS-B link, to detect threatening aircraft and provide an onboard alert to the flight deck crew. The alert is again presented in the primary flight display and the navigation display. A caution is presented in amber as the alerting system first detects the threat as it starts to evolve. As the danger becomes imminent based on the computations associated with the alerting algorithms, a red (level three) alert is issued in the flight deck of the protected aircraft. The (amber) caution alert and the (red) warning alert in the configurations under study at LaRC are accompanied by specially designed displays of the threatening aircraft's path to allow the flight deck crew to quickly assess the nature and severity of the threat. In the concept, the red alert (Figure 9), a level three, requires the flight deck crew to execute the emergency escape maneuver as described above. Again this is an immediate, accelerating, climbing turn away from the approaching traffic and parallel runway to a heading of 45 degrees from the nominal approach heading. The version of the concept under study at LaRC displays information in the primary flight display and in the navigation display. A computer controlled voice message complements the displayed information with a "turn, climb, turn, climb, turn, climb," aural advisory when the level three alert is activated.

The concept design team at LaRC completed a fixed base simulation test of the initial concept in May 1996. In the test, sixteen pilots each flew 56 parallel approaches, with about one third of the cases presenting collision or near miss threats. The test subjects were line pilots from a number of airlines and air-freight companies. They were trained for the task, in a manner, similar to the way they are trained and tested for rejected takeoffs (RTO's) and category II approaches. The reaction time of the pilots in executing the turning maneuver and the closest approach were key parameters measured in these tests. Parallel approaches spaced 3400 ft. and 2500 ft. apart were examined in the initial study. The test findings show that under the conditions tested, all of the pilot reaction times were well under the two seconds targeted by the NASA design team, and that no trials resulted in violations of the 500 ft. minimal separations used for defining near misses in the parallel runway approach environment. The mean miss distance measured was in access of 1900 ft., with the closest encounter at 1183 feet.

A second phase of testing was completed in July 1996, at LaRC**.** The follow-up tests included new alerting algorithms and modifications to the displays based on observations and pilot comments from earlier tests. Runway lateral spacing was reduced to 1700 ft. and 1200 ft. Eight, two-member airline crews were tested in the second phase. The results were very promising for the 1700 ft. runway separation, with no encounters closer than the targeted 500 ft. miss criteria. The 1200 ft. case resulted in one encounter closer than the 500 ft. two dimensional near missed criterion used, and is regarded as questionable by the design team when the current experimental AILS technology is used.

The study at ARC was completed in August 1996, and explored application of TCAS concepts to the closely spaced parallel runway approach problem. This study showed that a display based on the TCAS formats, but enhanced with a higher resolution navigation display and specially designed alerting algorithms, resulted in better performance than the TCAS implementation using a conventional navigation display format. The performance with the enhanced display features and alerting algorithms resulted in no near misses and good pilot evaluations. The study at ARC investigated an autopilot coupled approach, in contrast with the manual mode used in the LaRC studies, and addressed the 4300 ft. and 2500 ft. runway spacing cases.

In interpreting these results it is important to realize that they show the feasibility of the AILS concept in initial testing in a research simulator environment and that a large amount of additional testing and validation is required before a concept of this nature could be implemented in the National Airspace System. Among the issues that must be resolved are the effects of wake turbulence considerations.

Appendix B

11.0 ATC Experiment Options and Down Selection Recommendations

Table Comparing Potential Levels of Simulation with Evaluation Parameters

Description of Simulation Level	Cost Factor	Time Factor	Where	Benefits	* Objectives 1	2	3	4	5	6	7	Comments and Recommendations
1. Complete arrival environment · Feeders (2 ea., all full sim.) · Final (2 ea., all full sim.) · Tower (1 or 2 ea., full sim.) · CC · CI	· high · staff: 7-8	· high	· ARC · Tech Center · Mitre	· high · most needed measurements · position interactions	H	H	H	H	H	H	H	- Inline with a live demonstration at a real facility, e.g. SFO. - viewed as more than we can manage, within time and resources
2. Full sim. of select position(s), alternative A · Tower - full simulation · Final - full sim., 2 ea. · Pseudo-Controller/scripts for other positions · CC/CI	· medium · staff: 4+	· medium - high	· ARC · Tech Center · Mitre	· high but limited · some position interactions	H	H	H	H	H	H	H	- viewed as not practical in the scope of resources available.
3. Software representation of non-targeted positions. Use # 2 type full sim. for ATC controller for select position(s) · Like # 2 except software sim non-selected positions. · CC/CI (combine, not tested)	· medium-high · staff: 3+	· medium - high	· ARC · Tech Center · Mitre	· high but limited · some position interactions	H	H	H	H	H	H	H	-viewed as not practical in the scope of resources available. -req. software development of pseudo controllers.
4. Full sim. of select positions, (minimized), alternative B · Tower full · Final- one full, one pseudo · Pseudo ATC or SW sim. of others	· medium · staff: 3+	· low-medium	· ARC · Tech Center · Mitre	· medium with limits · some interactions	H	H	H	H	M+	H	H	· first choice

Description of Simulation Level	Cost Factor	Time Factor	Where	Benefits	1	2	3	4	5	6	7	Comments
					* Objectives							
5. Full sim. of select positions (minimized), alternative C · Tower- Full Simulation · Others- pseudo or SW sim. · CC/CI combined	· low-medium · staff: 3	· low-medium	· ARC · Tech Center · Mitre	· medium with limits · limited interaction	M	H	M+	M-	L+	H-	H	· third choice
6. Full sim. of select positions (minimized), alternative D · Arrival full · all others pseudo or SW · CC/CI combined	· low - medium · staff: 3	· low-medium	· ARC · Tech Center · Mitre	· medium with limits · limited interaction	M	H	M+	M-	L+	M+	H	· fourth choice
7. Split simulation runs between 5 and 6 above	· low - medium · staff: 3	· low-medium	· ARC · Tech Center · Mitre	· medium with limits · limited interaction	M	H	M+	M-	L+	H	H	· second choice
8. All ATC controllers Pseudo realistic display - demonstration essentially separate from tests	· low-medium · staff: 1	· low-medium	· ARC · LaRC	· no ATC data · support sim. · good demo.	N	M	N	N	N	N	H	· fifth choice
9. Pseudo controller positions only	· low · staff: 1	· low	· ARC · LaRC	· no ATC data · supports sim.	N	N	N	N	N	N	H	· fall back

* Experiment Objectives (H = high, M = medium, L = low, N = none):

1. Validate that the AILS requirements and processes are realistic at the ATC positions
2. Demonstrate to stake holders example of ATC position functions
3. Provide an opportunity to identify problems that might have been overlooked in earlier planning
4. Explore human factors aspects of AILS at the ATC position, including controller workload
5. Examine aircraft-ATC interaction from the ATC perspective
6. Provide an opportunity to identify, design, and demonstrate any needed new ATC interface features
7. Support the flight deck simulation with acceptable ATC simulation

Appendix C

12.0 ATC Procedures and Phraseology

12.1 Independent Straight-in AILS Approaches (See Figure 2)

1. Automated radar handoff of aircraft from feeder controller to final controller including communications transfer.
2. NASA 557, Approach, fly present heading, descend and maintain 5000, over.
3. NASA 557, reduce speed to 210.
4. Turn base leg (where applicable).
5. NASA 557, traffic eleven o'clock, 5 miles, a heavy Boeing 747 at 4000 turning final for AILS Runway 28 Left. Report traffic, over...
6. NASA 557, turn right heading 250.
7. Altitude assignment as appropriate.
8. NASA 557, two miles from Alto, maintain 5000 until established on the localizer, cleared AILS Runway 28 Right Approach.

   (about nine miles from runway)
9. NASA 557, three miles from Palo, contact tower on 120.5.
10. Tower, NASA 557 is two and one half miles outside Palo for 28 right.
11. NASA 557, Tower, Runway 28 Right, cleared to land. Traffic a heavy Boeing 747 eight o'clock, landing Runway 28 Left, over.
12. Complete approach, missed approach or EEM.

12.2 Segmented Approaches (See Figure 3)

1. Automated radar handoff of aircraft from feeder controller to final controller including communications transfer.
2. NASA 557, Approach, turn left heading 090, then descend and maintain 5000, over.
3. NASA 557, reduce speed to 210.
4. NASA 557, turn right heading 190.
5. NASA 557, traffic eleven o'clock, five miles at 4000, a heavy Boeing 747 turning final for AILS Runway 28 Left . Report traffic, over...
6. NASA 557, turn right heading 240.
7. Final controller monitors progress.
8. NASA 557, two miles from Alto, maintain 5000 until established on the localizer,

cleared Segmented AILS Runway 28 Right Approach.

(about nine miles from runway)

9. NASA 557, three miles from Palo, contact tower on 120.5.

10. Tower, NASA 557, two and one half miles outside Palo for 28 right.

11. NASA 557, Tower, Runway 28 Right, cleared to land. Traffic a heavy Boeing 747 eight o'clock, landing Runway 28 Left, over.

12. Complete approach, missed approach or EEM.

Appendix D

13.0 Air Traffic and Operational Data on U.S. Airports with Parallel Runways

(A separate document. See Reference 4)

Appendix E

14.0 Suggested AILS-ATC Experiment Plan, Seattle-Tacoma Terminal Model

(To evaluate one local controller and one final controller position)

14.1 Introduction

A simulation of the Seattle-Tacoma (SEA) terminal area environment has been chosen to study parallel runway operations where the approaches are spaced 2500 ft. apart. This selection is based on the knowledge that construction has started on a new runway 2500 ft. west and parallel to the existing runway 16L/34R. The purpose of this study is to further validate that the AILS process can be implemented in a simulation of a real world terminal environment. Two thousand five hundred feet is the targeted minimum lateral spacing for the first independent AILS operations. Seattle-Tacoma appears to be the terminal area that will have parallel runways spaced at 2500 ft. apart, and that is projected to have a capacity problem that can potentially be helped by AILS technology. The AILS approaches in this study will be straight-in as opposed to segmented.

The approach to developing this plan is to assume that the experiment can be conducted either as an integrated part of a flight deck experiment with a high fidelity real-time flight simulator or else as a stand alone simulation. As a stand alone simulation, it is anticipated that at least one pseudo-pilot facility, or several low fidelity flight deck simulators, will support the experiment by representing the roles of the aircraft involved in the scenarios.

The scenarios should include the entire relevant airspace operation beginning in the feeder controller's airspace, through the final controller's airspace, and handoff into the tower local controller traffic pattern continuing to landing, execution of the emergency escape maneuver or missed approach. If either the emergency escape maneuver (EEM), or a missed approach is executed, the aircraft should continue through the airspace that would normally be impacted. It is estimated that the flights should be extended for approximately three minutes beyond the EEM execution time until the two aircraft involved in the initial incident are on stable paths with appropriate clearances, and the impacted ATC positions have dealt with the initial phase of the emergency situation.

The Seattle-Tacoma terminal area affords an opportunity to test in an environment where only two controller positions are tested and yet valid and valuable data can be acquired. It is evident from the analysis and discussions of the operations in this terminal area that, in an intrusion event, it is unlikely that the track of either aircraft would proceed into the airspace of the departure controller. Even if one does proceed in that direction, it would be very similar to a missed approach operation and managing such an event is a relatively routine occurrence, or at least a type of event with which the system has considerable experience. Therefore, this experiment will be developed to test a single local controller position (LC) and a single final controller position (AR). All other controller positions and tasks will be represented by a pseudo-controller operation, including a second local controller position, the departure controller position, and the feeder controller position. Coordinator positions may be exceptions to this general methodology.

As discussed in the main text, each facility, the tower and the TRACON, will have a coordinator position, CC (cab coordinator) in the tower, and CI (radar coordinator) in the TRACON. In the event of an emergency condition such as an intrusion incident, these positions will normally intervene, join in with the team, and make some of the decisions about the resolution of the situation, and instruct and advise the LC and AR positions on what action is to be taken. They will also assist with the coordination between the facilities (tower and TRACON) and positions. Therefore, the operation will not be a process involving only the LC and the AR, but it will include inputs and actions completed by the CC and CI.

14.2 Description of the Seattle-Tacoma International Terminal Area

This study plan assumes that a new runway has been completed at the Seattle-Tacoma International airport so that the planned configuration is the three parallel runway layout illustrated in Figure 12. As illustrated in the figure, the plan assumes that the approach to the new runway 16R is used as a parallel approach along with runway 16L. The planned runway 16R is located 2500 ft. west of the existing runway 16L, while the existing runway 16R will be re-designated runway 16C, and will be used primarily for departures. Heavy jet traffic will in all probability use runway 16L. The planned new runway 16R will be approximately 6800 ft. in length while the existing runway 16L is 11,900 ft. Heavy jets, like the B747-400, will typically require use of runway 16L for departure operations. The runway 16C can handle the departing traffic; however, in IFR conditions it must operate as a single runway operation, because of the proximity of the other two runways.

The assumed layout of the airspace in the Seattle-Tacoma terminal area is illustrated in Figure 12. Study of the Seattle VFR Terminal Area Chart and existing FAA approved Standard Instrument Approach Procedures confirms that there are no obstacles along the approach path to runway 16L and the planned runway 16R within a proximity that would prevent the use of a turning and climbing AILS emergency escape maneuver. The terminal air traffic operation is supported through a four corner post airspace configuration and traffic flow pattern.

It is assumed that two separate tower local controller (LC) positions will control traffic to runways 16L and 16R, and that they are physically located in the same tower cab, so one CC position is involved in the coordination. It is not clear at this point whether it is likely that SEA will pair traffic for landing on runways 16L and 16R. It seems that pairing would be done to maximize the takeoff and landing capacity in an independent operations. It seems reasonable to pursue a paired traffic operation because of the dependency of the three runways due to their close proximity. (This needs to be deliberated in more detail.) Note: In this case they would probably pair the arrival traffic to be able to use the center runway for departures. The requirement is that runways closer than 2500 ft. laterally be treated as one runway during approaches in IFR conditions. Also, another consideration is the arrival flow to Boeing Field, four miles north, which has a direct effect on the arrival flow to SEA.

The follow is an attempt to summarize the restrictions and requirements regarding departing in IFR conditions on parallels runways closer than 2500 feet:

a. If two aircraft, large or small, are departing, the first departure has to be a minimum of 1 NM ahead of the next departure and on a 15 degree diverging course.

b. If two heavies are departing, a 5 NM mile longitudinal spacing must be maintained at all times.

c. If a heavy and a large/small are departing, it is optimal to depart the large/small first and the heavy can depart 1 NM behind with the large/small having turned to a 15 degree diverging heading.

d. With a heavy or a B-757 departing first, standard separation must be applied. The 15 degree diverging rule is not applicable.

In conclusion, the comments given above relate to how one must model use of the three parallel runways at the Seattle-Tacoma airport. And, any credible study must be conducted with these constraints in mind.

14.3 Experiment Objective

The objective of this experiment is to determine the effectiveness of the tower local controller, and the final controller in performing the tasks required in an AILS operation. The test should determine effectiveness of the controllers handling the two aircraft which have departed from nominal operations, the erring intruder flight and the second AILS protected flight that executes the emergency escape maneuver to avoid a mishap. The emergency escape maneuver executed by the aircraft will be those used in the flight deck centered AILS testing including the turning-climb and climbing only escape maneuvers. The test will also asses the acceptability of other features of the AILS process, including the initial transfer of responsibility to the flight deck crew for separation from traffic operating on the parallel approach; while air traffic controllers retain responsibility for longitudinal in trail separation.

14.4 Scope

The testing will allow evaluation of the effectiveness of the tower local controller and of a final controller. Those two positions will be fully simulated with no artifacts of the experiment hindering these controllers' performance of realistic operations. The other air traffic controller position functions will be represented in the experiment in a manner that supports the flight deck experiment (if conducted in concert) and the ATC experiment. No attempt will be made to represent other ATC functions realistically, but the interaction with a CC or CI position needs to be convincing from the perspective of the LC and the AR test subjects. A pseudo-controller function will simulate all other functions of the ATC system that need to be represented in the simulation. The pseudo-controller is assumed to be a person with software support that could include a high level of automation to support the requirements. The pseudo-controller should operate in the experiment in a manner that aids in presenting a realistic environment for the subjects of the experiment with no requirement for realism at the pseudo-controller station.

14.5 Assumptions

It is assumed that the AILS parallel approaches are controlled directly by the LC controlling traffic to the particular runway. That LC will be responsible for re-establishing control and assuming responsibility for the AILS traffic once an incident or emergency escape maneuver has occurred. The LC's will be expected to manage the two erring aircraft, including the completion of any necessary coordination with other controller positions. The expectation is also that they will safely manage the traffic not directly involved in the intrusion incident that may be continuing on the approach to the runway. The LC must also continue, as appropriate, duties related to departure traffic and traffic already landed but not handed off to ground control.

14.6 Independent Variables

These will be the same independent variables used in the planned AILS simulation flight deck testing except for Item 4. Possible independent variables are the following:

1. Segmented vs. Straight-in.
2. Vertical vs. turning emergency escape maneuver (EEM).
3. Runway separation.

(these variables have not been finalized for the flight deck experiment)

4. Nominal route for the two aircraft after the emergency escape maneuver.

At this time the Ad Hoc Team is not recommending that additional independent variables be included that are particularly selected to explore ATC related issues, except for Item 4 in the list above. It is not expected that introducing the route of the erring traffic will increase the number of runs that would otherwise be executed in the experiment. That part of the testing is conducted after the other independent variables of the test have been covered in the experiment. It is essentially an add on to the length of each run, approximately three minutes. The primary purpose of this study, from the ATC perspective will be to establish, based on experimentation, that the proposed ATC processes are feasible.

14.7 Dependent Variables

1. Subjective evaluations by the subject controllers: An evaluation form is at the end of this section

2. Subjective evaluation/rating by an observing expert: This will need to be done either in real time or during an off-line viewing of a video tape of the operation. Video taping will be a requirement of the operation. A question will be whether to video tape each run at the four different control stations. The probable answer will be that this is a requirement for the data collection in the experiment; therefore, it will need to be done.

3. 3. Objective measurements: Attempts to define objective measures of ATC performance, that will be sensitive to changes in the experiment variables, presented a difficult task for the ad hoc team. The list that follows is made up of potential measures suggested by the Ad Hoc Team for consideration, more deliberation on these possibilities is needed.

    3.1 coordination with other control positions
    3.2 communication instructions with conflicting aircraft
    3.3 communication instructions to other aircraft not in direct conflict
    3.4 errors made
    3.5 other aircraft allowed to violate separation standards
    3.6 timeliness of instructions to other aircraft
    3.7 use of incorrect ATC phraseology
    3.8 secondary task - induced situations to be managed
        3.8.1 airborne and not switched to departure
        3.8.2 disabled aircraft on runway / aircraft too slow exiting runway
        3.8.3 departing aircraft delays too long, before starting take off roll
        3.8.4 There might be opportunities for secondary task measurements in the runway crossing situations in the experimental SEA environment.

4. Measuring the controller's ability to re-establish control and responsibility: One measurement of interest is the amount of time that elapses before the controller accepts responsibility for separation of the erring aircraft. The request for the air traffic controller assistance will come from the flight deck of the evading aircraft, in the format: "Tower, aircraft ID, executing an emergency escape maneuver to avoid traffic, request instructions." When the tower issues instructions that will constitute ATC (the LC in this case) re-establishing control and accepting responsibility for separation of the aircraft from all traffic. A roger, unable, or standby reply from ATC, or a controller stating that radar targets are merged, shall be interpreted to mean that the controller has not accepted responsibility for control and separation; and that aircraft must continue to provide separation from each other using AILS technology. To accept

control and provide separation of the evading aircraft, targets must be separated so that the controller can reestablish identity and provide separation. The same positive action protocol shall be applied to the intruder aircraft in order to assume responsibility for separation of aircraft.

The measurements made will be the time from the request of the crew of the evading aircraft for instructions until the controller acknowledges by issuing control instructions. Related to this will be a record of the initial reply of the controller, e.g., whether a “Standby” or “ other control instruction, ...”

Additional variables for consideration:

1. Number of communications to coordinate with other controllers, counted from video tape recording.
2. Number of communications to the two aircraft involved in the incident, counted by review of tape recording, communication line switches.
3. Time elapsed from the start of the incident until traffic flow is stabilized
   This will require a clear definition of stabilized traffic flow:
   - completed instructions to both aircraft that fit them into the pattern
   - No further unusual adjustments to any aircraft to accommodate
   - possibly use separate measurements for each of the two aircraft
4. The time until an aircraft is allowed to depart safely might be a measurement of the stabilized traffic flow pattern.
5. A recorded switch should be put in the subject controllers station to be activated by the controller as soon as the start of an event is recognized.

14.8 Experiment Setup

The assumption in developing this plan will be that four individuals will be involved in the ATC testing and support of the experiment, not including a test conductor and any evaluators that may be necessary:

1. A local controller position will be evaluated in the AILS processes.
2. A final controller position will be evaluated.
3. A coordinator; however, it is not clear whether one coordinator can do the job for both the tower and TRACON.
4. A pseudo-controller will carry out the other ATC support functions: A second AR position, a second local controller position, any feeder controller positions and, any adjacent sector positions necessary.

The equipment required for the simulated air traffic controller stations in the experiment is indicated in Table E1.

Table E1.- Simulator Equipment Requirement

		AR	Tower LC	PPC	CC/CI
	Simulation Equipment				
1	radar display/software	FDAD	DBRITE	PC monitor	PC monitor
2	air to ground AILS alert	x	x		
3	ground generated alert	x	x		
4	vox radio com channel	x	x		
5	com head, push-to-talk	x	x	x	
6	track ball and software	x	x		
7	coordination line to AR		x		x

8	coordination line to LC	x			x
9	coordination line to PPC	x	x		x
10	coordination line to CC/CI	x	x		

AR -Final controller LC -Local Controller PPC -Pseudo Position Controller
CC/CI - Cab Coordinator/Radar Coordinator

14.9 Conducting the Experiment

1. Briefing the controller subjects

This briefing, or at least some portions of it, should be conducted by an experienced controller:

- Define and explain the AILS process
- Define and explain the SEA terminal area and the additional runway
- Discuss the assumed traffic flow pattern
- Discuss take-off and landing operations at the airport
- Define the role and expectations of each position in the AILS process
- Discuss the role of the local controller in EEM's
- Discuss any assumed facilities policies regarding EEM's
- Underscore that this is an evaluation of the AILS process and whether it is practical to expect controllers to manage tasks as defined
- Discuss the simulated controller positions and test hardware
- Describe the debriefing forms: a. each run b. each session

2. Practice runs for the controllers

Prior to data collection in a given position, the subjects will be given a practice session which will include a minimum of three AILS intrusion incidents with emergency escape maneuvers. The practice operations should continue until the subject controllers feel comfortable that they understands the requirements and can manage the tasks required at the position. The initial practice session with a given controller group will include having the controller complete an example Run Evaluation Form for each of the types of operations (normal landings, missed approaches, AILS emergency escape maneuvers).

3. Test Session for Data Collection

A session will consist of a one hour operation of traffic flow into the SEA terminal area. It will include 20 normal landings, 5 missed approaches, and 5 intrusions incidents. After each missed approach, each intrusion incident involving a emergency escape maneuver, and 5 of the normal runs, the simulation will be frozen and the controllers requested to complete a Run Evaluation Form. Approximately five minutes will be allowed to complete the forms. After completing the form, the simulation will be reactivated from the state at which it was frozen. The total operating time for a session will be approximately two hours and 15 minutes.

If the test subjects are brought in as a pair, assuming each is qualified to operate in each position, it will then be feasible to get a set of data from each subject in the two positions being tested during a one or two day operation. A session will consist of the data collected with a given subject operating in a single controller position. It will consist of one hour of operation with approximately 30 aircraft making an approach to each of the two runways. After completing a session of operation in a particular position, each controller will be requested to complete an evaluation form covering the task requirements in the respective position.

14.10 Scenarios for the Two Aircraft After the Intrusion Incident

If a live flight deck simulator is used, only the path of the intruder prior to the emergency escape maneuver can be preprogrammed. As the subject air traffic controller assumes responsibility for the aircraft, the intruder aircraft becomes a pseudo-pilot controlled aircraft, a transition initiated when the first ATC instruction is given to it. Pseudo-pilot input to respond to controller instructions will execute the change over.

If a live flight deck simulator is not used, a pseudo-pilot can represent the evading aircraft with the emergency escape maneuver automatically initiated. After the incident starts the pseudo-pilot operation can represent the operation of both the aircraft involved in the incident.

Figures 13 through 16 present incident scenarios for the two aircraft including the route of the two aircraft involved after the intrusion incident. The path of the intruder aircraft can be pre-programmed up to the start of the emergency escape maneuver. When the scenario includes the intruder maneuvering in response to ATC instructions, the pseudo-pilot will make inputs to control the path of the intruder, alternately in some cases, the intruder aircraft will be scripted to not respond to ATC instructions.

14.11 Methods for Representing the Intruder Trajectories in the Scenarios

The following are some thoughts on how to conduct the simulation that include options to use a real time flight deck simulator or else to operate an ATC role study separate from a real time flight deck simulation activity. *(The items listed capture the main elements of two ways to conduct the experiment. The Ad Hoc Team will try to clarify this discussion as soon as time permits)*

- Intruder and evader fly pre-recorded tracks taped in the flight deck simulation study (or some other source) until the evader pseudo-pilot requests air traffic controller instructions. The two aircraft are on different tower communication frequencies, with different LC's.

- The evading aircraft, after executing the initial emergency escape maneuver, should contact the local controller.

- Upon deviating from the final approach course with a control problem, wake turbulence upset or wind shear encounter, as examples, the intruder pseudo-pilot should request ATC instructions.

- The evader aircraft continues on its pre-recorded track (if a pseudo-pilot is used for the evader, as might be the case if a real time flight deck simulator was not used) until the test local controller provides instructions. The idea here is that the prerecorded tracks of the evader and intruder will have been created simultaneously, e.g. tracks of the two aircraft from the LaRC AILS piloted simulation study. On receiving instructions, the evader aircraft pseudo-pilot executes the instruction. An evader pseudo-pilot input will disable and override the pre-recorded track. Clearly, if a real time flight simulator is used, the evader track will not be prerecorded, and the evader flight deck would execute the emergency escape maneuver, contact tower, and comply with instructions.

- The intruder aircraft should be on a different local control frequency than the test local controller.

14.12 Recommendation

The bottom line seems to be that this is much more than the LaRC AILS staff can do with the level of effort normally available through resources for testing. The coordination task to accomplish such an experiment along with operating a piloted simulation study is enormous. In any such experiment the ATC testing should be conducted by ARC, the FAA Technical Center, a contractor that has experience in conducting this type of research, or a team comprising elements of these entities. There could possibly be LaRC participation, but the lead in such an experiment should be from another aviation laboratory. Testing of the ATC processes can conceivably be done disjoint with the piloted simulation testing. Pseudo-pilot capabilities and canned trajectories could be used judiciously to represent the flight decks in such an experiment.

Appendix F

15.0 Suggested AILS-ATC Experiment Plan, San Francisco Terminal Model

The San Francisco (SFO) terminal area environment (Figure 17) presents a number of issues related to the composition of a study of this nature. One such issue is the question of which air traffic controller positions are likely to be impacted by an AILS emergency escape maneuver (EEM). The analysis of the Ad Hoc Team indicates that any of the positions in the terminal area airspace are candidates for traffic diversions during an emergency procedure. An incident involving an EEM will by definition start in the airspace of the local controller (LC) and proceed, depending on a number of factors, into the airspace of a final controller (AR), or remotely that of the departure controller or feeder controller.

Regardless of the initial direction and circumstances, the immediate objective of the air traffic controller is to safely guide the two erring aircraft back into the arrival stream as expeditiously as possible. Having an aircraft proceed to a holding fix is not a desirable option from the air traffic controllers' perspective. When the LC or AILS monitor assumes responsibility, the objective becomes to insure separation of all traffic involved and to handoff the erring aircraft to the final controller directly if possible, avoiding an intrusion into departure airspace. A second option is for the LC or AILS monitor to handoff the aircraft to the departure controller with the expectation that position will direct the aircraft back to the arrival position airspace via the feeder controller and to the final controller. These decisions are coordinated and agreed on by the controllers involved as they view the incident in progress. They must work together as a team to get the situation resolved and direct the deviating aircraft back into the arrival stream as efficiently and safely as possible

15.1 Background

The approach to developing this plan is to assume that the experiment can be conducted either as an integrated part of the flight deck experiment with a real-time flight simulator or else as a stand alone simulation. As a stand alone simulation, it is anticipated that at least one pseudo-pilot facility or a number of stand alone flight deck simulators will support the experiment by representing the role of the aircraft involved in the scenarios.

The scenarios should include the entire relevant airspace operation beginning in the feeder controller's airspace, through the final controller's airspace, to the tower local controller's traffic pattern to landing or execution of an EEM, or missed approach. If an EEM is executed, the aircraft should continue through the airspace that would normally be effected. It is estimated that the flights should be extended for approximately three minutes beyond the EEM execution time until the two aircraft involved in the initial incident are on stable paths with appropriate clearances and the impacted positions have stabilized their operations.

15.2 Assumptions

It is assumed that a single local controller position will operate the San Francisco tower traffic, inasmuch as that is the case in the current SFO tower operation. This assumption is based on discussions with SFO air traffic staff personnel indicating that every effort has been made previously to define a safe operation that divided the tasks between two controllers. However, the conclusion has always been that operating with one controller makes the most sense from the vantage point of maintaining the complex coordination needed for the runway configuration.

Given the single local controller position in IFR operations, the use of an AILS monitor controller is recommended in a SFO application of AILS. The task of the AILS monitor will be distinctively different from that of existing final monitors (FM) operating in other simultaneous independent ILS approach environments. The SFO AILS monitor, assumed to be a TRACON position, will perform the following functions:

(1) Monitor aircraft operating on the parallel approaches.

(2) Issue appropriate speed advisories to those aircraft to assure same stream longitudinal spacing or have aircraft execute a missed approach where necessary for spacing violations. The logic is to minimize this additional workload on the LC where feasible.

(3) In the event of an AILS emergency escape maneuver, the AILS monitor will assume ATC control of each erring aircraft as the flight deck crew reports its departure from its clearance, and appropriate separation conditions or identification conditions are met.

(4) During the process of resolving the mishap, the AILS monitor will coordinate with the control positions impacted and handoff the erring aircraft to the appropriate controller.

15.3 Experiment Methodology

The tests should be conducted in a realistic traffic environment that represents departure traffic as well as approach operations. It is not clear whether the testing has to be with SFO controllers in the final analysis; however, it is evident that the job of the SFO local controller is different and perhaps more complex than the local controllers at other airports. Training will probably be a very significant issue. It is doubtful that in an experiment, LaRC experimenters will be in a position to train subject controllers to the levels required to perform the task with the proficiency of experienced SFO local controllers. This raises some issues discussed in the topics which follow, related to considerations for the experiment.

3.1 <u>Confounding with lack of training for the SFO task</u>

The problem is that if effects are observed, we will not be able to attribute the cause to excessive workload demands of the proposed process, or alternatively to lack of adequate training for the air traffic controller subjects in the experiment. Therefore, why attempt to do such an experiment, unless we get a group of controllers from SFO, or do what ever it takes to adequately train the controllers. Note: It would be more efficient to use controllers that are familiar with the airspace and operation.

3.2 <u>Use a control condition</u>

Alternately, a control condition could be used in the experiment in which the subjects do the required task without the presence of the independent variables under study to assess the <u>usual</u> <u>values</u> of the measures. The control condition would provide a measure of the controller's task performance without the impact of the test variables. This could possibly be a very costly addition, although there are some circumstances which might help with this.

One consideration which implies perhaps not such a costly item is that we normally conduct half of the runs or more without intrusion incidents. These runs could provide the control condition. We should expect that no controller effects would occur in that environment or at least that the performance is well within tolerance. This would provide the baseline of the experiment. If the effects (dependent variable values) observed in this control condition are examined and compared with the observed effects in the different levels of the test variables to determine the change, this will be a useful measure.

This seems to be a defensible methodology. What we will be comparing are the effects observed when no intrusion incidents occur versus when intrusions do occur. If the control condition effects are unusual, based on expert opinion, it could cause some questions about the validity of the experiment, and therefore weaken or invalidate the results. However, it is not clear to what extent such a circumstance would degrade the validity of the experiment. If the control condition effects are not far from expected levels it would be expected that the experiment is reasonable all the way around. Yet, the most important measure will be the difference in the control condition measurements and those of the experimental test conditions. The problem with this approach is that it is not clear whether similar results would be measured with fully trained SFO controllers, if they were not tested.

It might further help the argument if the control condition involved approaches with a conventional missed approach in IFR conditions. This is a nominal occurrence in the terminal airspace system. Yet, it more resembles the AILS EEM operation than a nominal flight to landing.

Another possibility is that the control condition could be aircraft executing an EEM because of an intruder incident in VFR conditions. The idea here is to simulate VFR flights into SFO with an intruder incident as the baseline for comparing control performance. It seems that the controllers would normally immediately intervene in such a situation similar to how they would be requested to assume control in the proposed AILS environment. This would require a high fidelity tower simulation with out of the window viewing of the airport and surrounding airspace. This would be a highly credible control condition.

Indeed, it seems that none of the circumstances explored above provides a clear methodology that avoids a need to have fully trained SFO controllers. A step which could be taken in the methodology is to include two or three SFO controllers in the test subject group. This would allow comparison of the performance of the other controllers with that of the SFO subjects.

3.3 <u>Run the risk of getting a totally favorable outcome</u>

On the other hand, if the experiment was completed using available subjects (not including experienced SFO controllers) or with a minimal number of experienced SFO controllers and a convenient level of training, and all performance is found to be within acceptable limits, the results would be a favorable data set supporting the AILS process. All things considered, it seems that it would be most desirable to include two or three SFO controllers in the methodology as a minimum. A control condition should be included to allow assessment of the sensitivity and sensibility of the dependent variables.

15.4 Scope

The testing will allow evaluation of the effectiveness of the tower local controller (LC), the AILS Monitor (MR), and of a final controller (AR). Those three positions will be fully simulated with no experiment artifacts hindering these controllers' performance of realistic operations. The other air traffic controller position functions will be represented in the experiment in a manner that supports the flight deck experiment (if conducted in concert) and the ATC experiment. No attempt will be made to represent other ATC functions realistically, i.e. beyond the extent necessary for a realistic appearance to the test subjects. A pseudo-controller function will simulate all other functions of the ATC system that need to be represented in the simulation. The pseudo-controller is assumed to be a person with software support that could include a high level of automation to support the requirements. The pseudo-controller should operate in the experiment in a manner that aids in presenting a realistic environment for the subjects of the experiment with no requirement for realism at the pseudo-controller station.

15.5 Experiment Objective

Determine the effectiveness of the tower local controller, the AILS monitor, and a selected final controller in performing the tasks required in an AILS operation focusing on the segmented approach. The test should determine effectiveness of the controllers handling the two aircraft that have departed from nominal operation, the erring intruder flight and the second AILS protected aircraft that executes the emergency escape maneuver to avoid a collision. The emergency escape maneuver executed by the aircraft should be those used in other AILS testing including the climbing only escape maneuver.

The test will also asses the acceptability of other features of the AILS process, including the initial transfer of responsibility to the flight deck for separation from traffic operating on the parallel approach; while air traffic controllers retain responsibility for longitudinal in-trail separation.

15.6 Independent Variables

The independent variables will be the same as those discussed in the test plan for the SEA terminal area model presented in Appendix E.

15.7 Dependent Variables (Measurements of the Experiment)

The dependent variables will be the same as those discussed in the test plan for the SEA terminal area model presented in Appendix E.

15.8 Experiment Setup

The assumption in developing this plan will be that five individuals will be involved in the ATC testing and support of the experiment, not including a test conductor and any evaluators that may be necessary:

1. A local controller (LC) position will be evaluated in the AILS processes.
2. A final controller position will be evaluated in the AILS processes.
3. An AILS monitor (MR) will be evaluated.
4. A pseudo-controller will carry out the other ATC support functions: A second AR-final controller, two feeder controllers, adjacent sector controllers, a departure controller, and a tower and TRACON coordinator.

The equipment required for the simulated air traffic controller stations in the experiment is indicated in Table F1.

Table F1.- Simulator Equipment Requirement

		AR	Tower LC	MR	PPC	CC/CI
	Simulation Equipment					
1	radar display/software	FDAD	DBRITE	FDAD	PC monitor	
2	air to ground AILS alert	x	x	x		x
3	ground generated alert	x	x	x		x
4	vox radio com channel	x	x	x		
5	com head, push-to-talk	x	x	x	x	x
6	track ball and software	x	x			
7	coordination line to AR		x	x		x
8	coordination line to LC	x		x		
9	coordination line to PPC	x	x	x		

10	coordination line to CC/CI	x	x	x	x	x

AR - Final controller LC - Local Controller PPC - Pseudo Position Controller
MR- AILS Monitor Controller CC/CI - Cab Coordinator/Radar Coordinator

15.9 Conducting the Experiment

Same discussion as in the experiment plan for the modeled SEA terminal area presented in Appendix E.

15.10 Scenarios for the Two Aircraft after the Intrusion Incident

Figures 18 through 23 present incident scenarios for the two aircraft including the route of the intrusion incident. The path of the intruder aircraft can be pre-programmed up to the start of the EEM. When the scenario includes the intruder maneuvering in response to ATC instructions, the pseudo-pilot will make inputs to control the path of the intruder.

15.11 Recommendation

Same discussion as in the experiment plan for the modeled SEA terminal area presented in Appendix E.

Appendix G

16.0 Suggested AILS-ATC Experiment Plan, Minneapolis St. Paul Terminal Model

(To evaluate one local controller and one final controller position)

16.1 Introduction

The Minneapolis-St. Paul (MSP) terminal area environment (Figure 24) has been selected to test ATC integration of the AILS concept in an environment with closely spaced parallel runways. The lateral distance between the parallel runways 30L and 30R is 3380 feet. An additional benefit of testing in the Minneapolis-St. Paul environment is the existence of the Instrument Landing System Precision Runway Monitor (ILS PRM) already operational. This feature offers the potential for eventual flight tests of AILS systems in an environment where the PRM system could provide an additional margin of safety. The AILS approaches in this study will be straight-in.

The approach to developing this plan is to assume that the experiment can be conducted either as an integrated part of the flight deck experiment with a real-time flight simulator or else as a stand alone simulation. As a stand alone simulation, it is anticipated that at least one pseudo-pilot facility or low fidelity flight deck simulator will support the experiment by representing the roles of the aircraft involved in the scenarios.

The scenarios should include the entire relevant airspace operation beginning in the feeder controller's airspace, through the final controller's airspace, into the tower local controller traffic pattern for landing, execution of the emergency escape maneuver (EEM), or missed approach. If either the EEM or a missed approach is executed, the aircraft should continue through the airspace that would normally be impacted. It is estimated that the flight of the aircraft should be extended for approximately three minutes beyond the EEM execution time until the two aircraft involved in the initial incident are on stable paths with appropriate clearances and the impacted ATC positions have stabilized their operations.

The Minneapolis-St. Paul terminal area affords an opportunity to test in an environment where only two controller positions are tested and yet sound and valuable data can be obtained. It is evident from the analysis and discussions of the operations in this terminal area that, in an intrusion event, it is unlikely that the track of either aircraft would proceed into the airspace of the departure controller. Even if one does proceed in that direction, it would be very similar to a missed approach operation and managing such an event is a relatively routine occurrence, or at least an event with which the system has considerable experience. Therefore, this experiment will be developed to test a single local controller position and a single final controller position. All other controller positions and tasks will be represented by a pseudo-controller operation, including a second local controller position, the departure controller position, and the feeder controller position.

16.2 Minneapolis St. Paul Terminal Environment

Figure 24 presents an illustration of the Minneapolis-St. Paul terminal area. Its parallel runway pair, 12L/30R and 12R/30L, is crossed by a one thousand one hundred foot long runway 4/22. The usual traffic flow involves takeoff and landing operations on the parallel pair, most often to the 30L/30R pair, although the 12R/12L direction can be used with the ILS PRM approach as well.

Under the ILS PRM protocol in IFR operations, the parallel approaches to runways 30L and 30R are independent. However, based on information received from MSP, the normal practice is to operate the approaches in pairs. The traffic is paired about 20 NM from the airport with one aircraft on the left approach and the other on the right. Successive pairs are longitudinally spaced four to five nautical miles in trail. This pairing process creates a gap or hole in the landing stream that allows the controllers to get two departures off on the two runways before the next two arrivals. It is emphasized that there is no requirement to operate in this manner since the approaches are independent under ILS PRM protocol. Note: When the operation switches from a dependent operation to an independent operation, each stream of traffic is spaced approximately 5 miles in trail. The spacing of each stream is independent of the other stream. The runways are over 2500 ft. apart so they operate as independent departure and arrival runways.

16.3 Precision Runway Monitor at Minneapolis Airport

3.1 Authorization

The FAA authorized air traffic control (ATC) at Minneapolis-St. Paul airport to conduct simultaneous close parallel ILS PRM approaches beginning in October 1997. These approaches are conducted to runways 30L/R and 12L/R. A waiver had to be obtained because the runways were 3380 ft. apart and not 3400 ft. apart as required by ILS PRM.

3.2 Methodology

The ATIS broadcast will announce when the ILS PRM approaches are in progress, and the pilots will notify ATC on initial contact if they cannot meet the requirements to perform the approach. Each pilot will use two frequencies when conducting the approach, a primary frequency used to transmit and receive control instructions from ATC and a monitor only frequency to avoid a blocked transmission from ATC.

3.3 ATC Traffic Flow

Arrival and departure pushes occur at the same time, consequently departure spacing is provided when conducting approaches. Departures use both parallel runways. Four to five mile spacing on final approach is needed to provide enough time for departures.

A staggered approach traffic flow is set up until the flow reaches approximately 20 miles on final at which time they go to simultaneous independent ILS approaches. The PRM position is staffed at the beginning of each push. Consequently, that process is in place when the transition is made from staggered to simultaneous approaches.

It is assumed that an AILS operation would follow this same paradigm to achieve the necessary capacity on the runways.

16.4 Experiment Objective

The objective of this experiment is to determine the effectiveness of the tower local controllers and the final controller in performing the tasks required in an AILS operation. The test will determine effectiveness of the controllers handling the two aircraft which have departed from the nominal operation; namely, the erring intruder flight and the second protected flight that executes the emergency escape maneuver to avoid a mishap. The emergency escape maneuver executed by the aircraft will be those used in the flight deck centered AILS testing including the turning-climb and climbing only escape maneuvers. The tests will also assess the acceptability of other features of the AILS process, such as the initial transfer of responsibility for separation from traffic operating on the parallel approach to the flight deck crew while the air traffic controllers retain responsibility for longitudinal in-trail separation.

16.5 Scope

The testing will allow evaluation of the effectiveness of the tower local controller (LC) and a final controller (AR). These two positions will be fully simulated with no artifacts of the experiment hindering these controllers' performance of realistic operations. The other air traffic controller position functions will be represented in the experiment in a manner that supports the flight deck experiment (if conducted in concert) and the ATC experiment. No attempt will be made to represent other ATC functions realistically. A pseudo-controller position will simulate all other functions of the ATC system that need to be represented in the simulation. The pseudo-controller is assumed to be a person with software support that could include a high level of automation to support the requirements. The pseudo-controller should operate in the experiment in a manner that aids in presenting a realistic environment for the subjects of the experiment.

It is assumed that the AILS parallel approaches are controlled directly by the LC managing traffic to the particular runway. That LC will be responsible for re-establishing control and assuming responsibility for the AILS traffic once an incident or EEM has occurred. The LC will be expected to manage the two erring aircraft including the completion of any necessary coordination with other controller positions, safely manage the traffic not directly involved in the intrusion incident that may be continuing on the approach to the runway, and continue, as appropriate, duties related to departure aircraft and aircraft already landed but not handed off to the ground control position.

16.6 Independent Variables

The independent variables will be the same as those discussed in the test plan for the SEA terminal area model presented in Appendix E.

16.7 Dependent Variables

The dependent variables will be the same as those discussed in the test plan for the SEA terminal area model presented in Appendix E.

16.8 Experiment Setup

The assumption in developing this plan will be that three individuals will be involved in the ATC testing and support of the experiment, not including a test conductor and any evaluators that may be necessary:

1. A local controller position will be evaluated in the AILS processes.
2. A final controller position will be evaluated.
3. A pseudo controller will carry out the other ATC support functions: A second AR position, a second local controller position, any feeder controller position, a tower and TRACON coordinator positions, and any adjacent sector positions necessary.

The equipment required for the simulated air traffic controller stations in the experiment is indicated in Table G1.

Table G1.- Simulator Equipment Requirement

		AR	Tower LC	PPC	CC/CI
	Simulation Equipment				
1	radar display/software	FDAD	DBRITE	PC monitor	PC monitor
2	air to ground AILS alert	x	x		x
3	ground generated alert	x	x		x
4	vox radio com channel	x	x		
5	com head, push-to-talk	x	x	x	x
6	track ball and software	x	x		
7	coordination line to AR		x		
8	coordination line to LC	x			
9	coordination line to PPC	x	x		
10	coordination line to CC/CI				x

AR - Final controller LC - Local Controller PPC - Pseudo Position Controller
CC/CI - Cab Coordinator/Radar Coordinator

16.9 Conducting the Experiment

Same discussion as in the experiment plan for the modeled SEA terminal area presented in Appendix E.

16.10 Scenarios for the Two Aircraft after the Intrusion Incident

If a live flight deck simulator is used, only the path of the intruder prior to the EEM can be preprogrammed. As the subject air traffic controller assumes responsibility for the aircraft, the intruder aircraft becomes a pseudo-pilot controlled aircraft, a transition initiated when the first ATC instruction is given to it. Pseudo-pilot input to control aircraft will execute the change over.

If a live-crew simulator is not used, a pseudo-pilot can represent the evading aircraft, whose trajectory can also be canned until the incident transpires. (It is possible to consider incorporating the trajectories of the encounters of a previously conducted flight deck simulation study.) After the incident starts the pseudo-pilot operation can represent the operation of both aircraft involved in the incident.

Figures 25 through 28 present the example incident scenarios developed for the MSP experiment.

Appendix H

17.0 Subjective Evaluation Form for Controller Subjects

Subjective Evaluation Form for Controller Subjects

Position: LC AR (AILS)MR Date: Subject:

Display Requirements

1. Were you able to see the separation between targets when initially requested to assume control after the EEM?
   a. never b. occasionally c. frequently d. entire operation

2. Could all of the traffic impacted by the emergency escape maneuver be easily observed on your radar display?
   a. never b. occasionally c. most frequently d. entire operation

3. Was there traffic not in view on the radar display that needed to be accounted for in dealing with the problem?
   a. never b. occasionally c. frequently d. entire operation

4. Was there other traffic that was immediately impacted by the maneuvering of the erring traffic?
   a. never b. occasionally c. frequently d. entire operation

5. How many other aircraft (excluding the two initially involved in the conflict) were given vectors, speed adjustments, or watched closely to avoid an additional conflict after the emergency escape maneuvering started?
   a. none b. one or two c. three or four d. five or six e. larger number

Communication Requirements (after the missed approach or incident)

6. Was there adequate time for communication with your aircraft?
   a. never b. occasionally c. frequently d. entire operation

7. Did you feel that you were able to make all of the communications necessary to manage the task in a timely manner?
   a. never b. occasionally c. frequently d. entire operation

8. Did you make all of the communications with aircraft that you desired to make?
   a. never b. occasionally c. frequently d. entire operation

9. How often did you feel that the situation was on the verge of being out of hand?
   a. never b . occasionally c. frequently d. entire operation

10. How often did you sense that you had fallen behind the pace of what was needed to be done?
a. never b. occasionally c. frequently d. entire operation

Alerts

11. Did you find the caution (amber warning) alert adequate to cue you that an intrusion incident was evolving?
a. inadequate b. some deficiencies c. neutral d. adequate
e. above average

12. Did you find the caution alert a useful feature?
a. unnecessary distraction b. slightly distracting c. neutral
d. somewhat beneficial e. very beneficial

13. Was the audio tone associated with the caution alert useful?
a. unnecessary distraction b. slightly distracting c. neutral
d. somewhat beneficial e. very beneficial

14. Was the intrusion warning (red alert) adequate to cue you that an intrusion incident was in progress?
a. unnecessary distraction b. slightly distracting c. neutral
d. somewhat beneficial e. very beneficial

15. Did you find the red alert a useful feature?
a. an unnecessary distraction b. slightly distracting c. neutral
d. somewhat beneficial e. very beneficial

16. The aural sound warning of the intrusion incident was
a. an unnecessary distraction b. slightly distracting c. neutral
d. somewhat beneficial e. very beneficial

17. Do you feel that you could have done the job just as well without the alerts?
a. never b. occasionally c. uncertain d. usually e. always

Coordination Requirements (controller and coordinator)

18. Was there adequate time available to coordinate with the controller position to whom the erring traffic was handed off?
a. never b. occasionally c. uncertain d. usually e. always

19. Was the coordination process smooth and handled well?
a. never b. occasionally c. uncertain d. usually e. always

20. Were there unexpected situations to coordinate during the incidents?
a. never b. occasionally c. uncertain d. usually e. always

21. Did you complete all of the coordination communications you intended?
    a. never b. occasionally c. uncertain d. usually e. always

Other Traffic (*Control of traffic not immediately involved in the incident while the intrusion was in progress and immediately afterwards*)

22. Did you feel that there was adequate time available to continue your normal duties of controlling traffic not involved in the incident?
    a. too rushed b. slightly rushed c. adequate d. no effort

23. Did traffic not directly involved in the incident have to be maneuvered to resolve the problem and stabilize the traffic flow?
    a. no changes d. pushed to the edge
    b. slight maneuvering required e. unable to manage
    c. significant maneuvering required

24. Do you feel that the realism of the simulation was adequate to draw conclusions about the effectiveness of the controller in managing and resolving the situations you were exposed to in this study?
    a. excellent b. minor deficiencies c. average d. fair e. poor

Space for Comments on any Aspects of the Simulation:

Run Debriefing Form

Run no. ________ Date:
Subject no. ___ Position LC DR (AILS Monitor)MR AR

1. Prior to any incident (intrusion or missed approach), based on my workload, I would describe the task as
   a. not difficult b. somewhat difficult c. moderately difficult d. very difficult

2. Was the coordination among control positions adequate in this run?
   a. poor b. fair c. good d. above average e. excellent

   If you answered Poor or Fair , who did you have problems coordinating with?
   Circle response: LC DR MR AR CI CC other
   Comment:

3. Which other controllers did you coordinate with (directly communicate)?
   a. LC b. AR c. FR d. MR e. DR

4. Did you experience communication delays because the frequency was in use?
   a. big problem b. some problem c. mostly no problem d. no problem

--Stop here if no incident or missed approach occurred ----

5. Rate the difficulty of managing the erring traffic and bring the control of traffic in your airspace back to a stable flow.
   a. not difficult b. somewhat difficult c. moderately difficult d. very difficult

6. Planning my action to resolve the traffic conflict was
   a. not difficult b. somewhat difficult c. moderately difficult d. very difficult

7. The information available to assess the situation was
   a. significant deficiencies b. about right c. excellent

8. How would you rate the value of the caution and warning alerts?
   a. both very helpful c. caution helpful but warning unnecessary
   b. both unnecessary d. warning helpful but caution unnecessary

9. The impact of the intrusion on my control of traffic not directly involved in the incident was
   a. big problem b. some problem c. mostly no problem d. no problem

Local Control Only:

10. When you were first notified (by the pilot) that an incursion was taking place between the two aircraft, the targets
    a. were merged with no altitude separation.
    b. were not merged, but there was a loss of separation between the two aircraft.
    c. separated

Please Make Any Additional Comments on this Run on the Back of this Sheet.

18.0 List of Figures

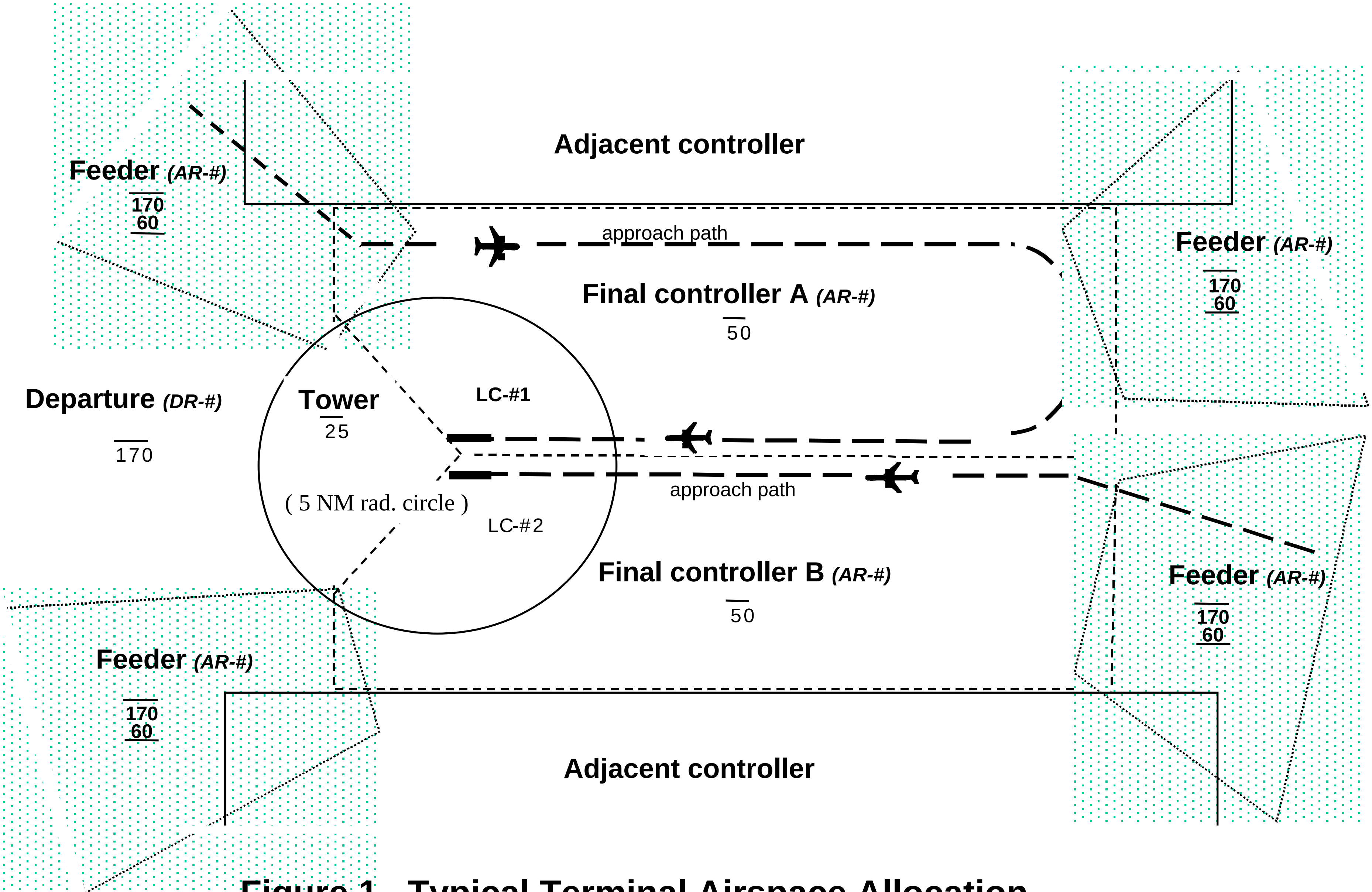
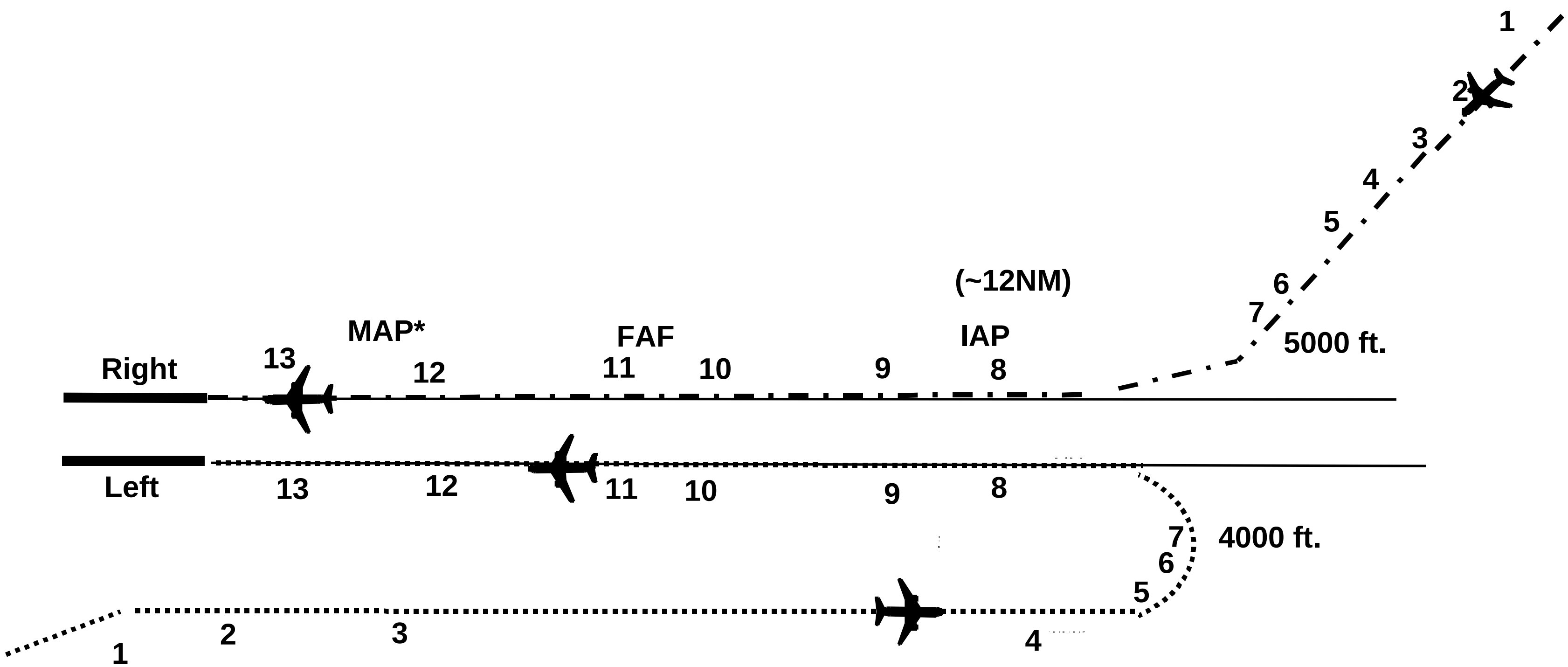


Figure 1. Typical Terminal Airspace Allocation

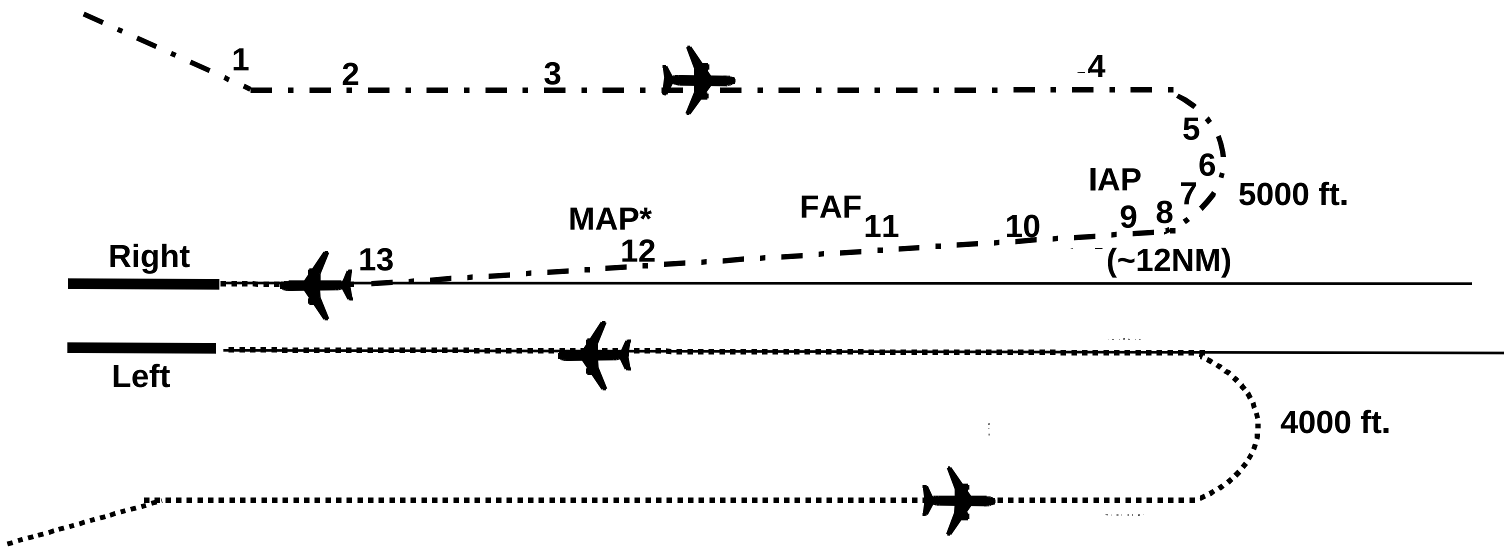


1. Feeder controller handoff to Final controller
2. Descend to 4000 ft./5000ft.
3. Speed adjustment (e.g. 210 kts.)
4. Turn base leg (where applicable)
5. Traffic pointed out
6. Turn to join localizer (≤30 deg.)
7. Altitude assignment as appropriate

8. Issue approach clearance
   (Flight deck crew assumes lateral separation responsibility)
9. Communications transfer to Tower prior to the Final Approach Fix (FAF)
10. Contact tower prior to FAF
11. Landing clearance from tower
12. Must be VMC at MAP *
13. Complete approach or missed approach

* Premise to continue approach is traffic in sight and flight deck crew to maintain visual separation.

Figure 2. Independent Straight-in AILS Approaches



1. Feeder to Final handoff
2. Descend to 4000 ft/5000ft
3. Speed adjustment (e.g. 210 kts)
4. Turn base leg (as appropriate)
5. Traffic Pointed Out
6. (Turn to) join localizer
7. Final controller monitors progress

8. Issue approach clearance
(Flight deck crew assumes lateral separation responsibility)
9. Transfer of control to tower prior to FAF
10. Contact tower prior to FAF
11. Landing clearance from tower
12. Must be VMC at MAP
13. Complete approach or missed approach

Figure 3. Independent Segmented AILS Approaches

(Place Holder)

Figure 4. Paired Staggered Approaches

Two elements of AILS flight deck centered technology aid pilots in:

- accurate flight path management
- conflict detection and resolution

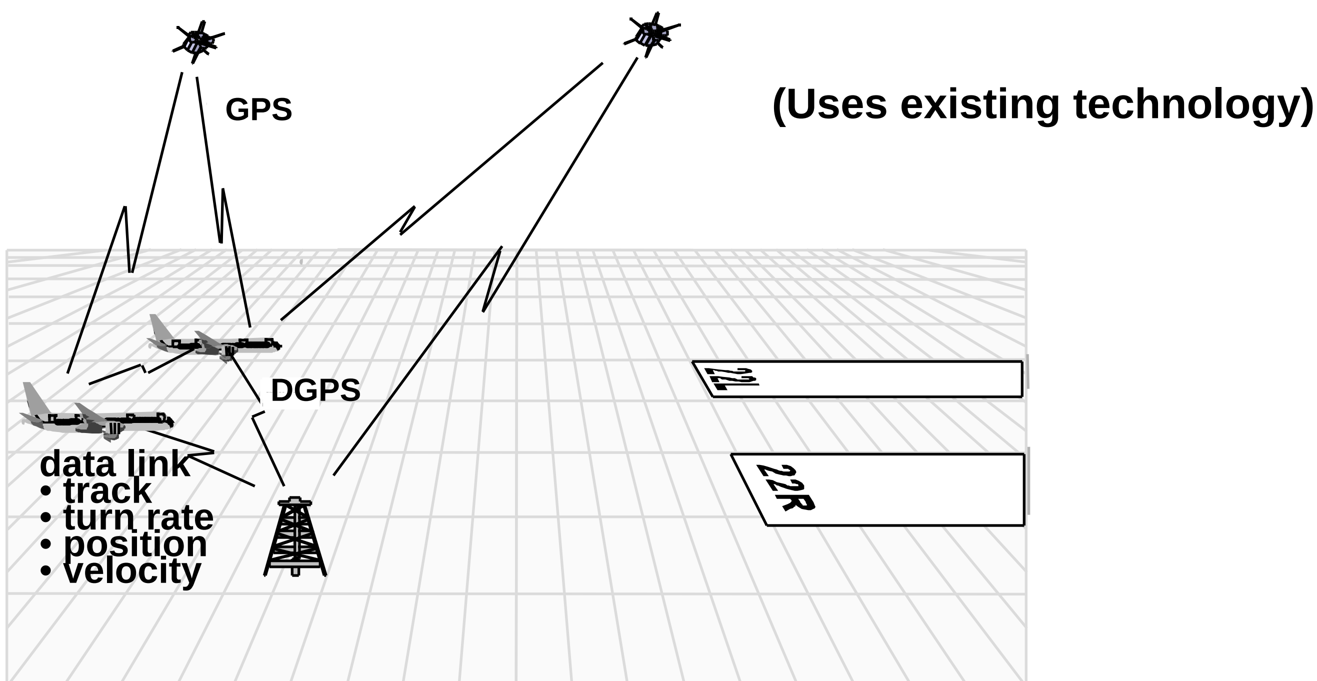


Figure 5. The AILS Concept

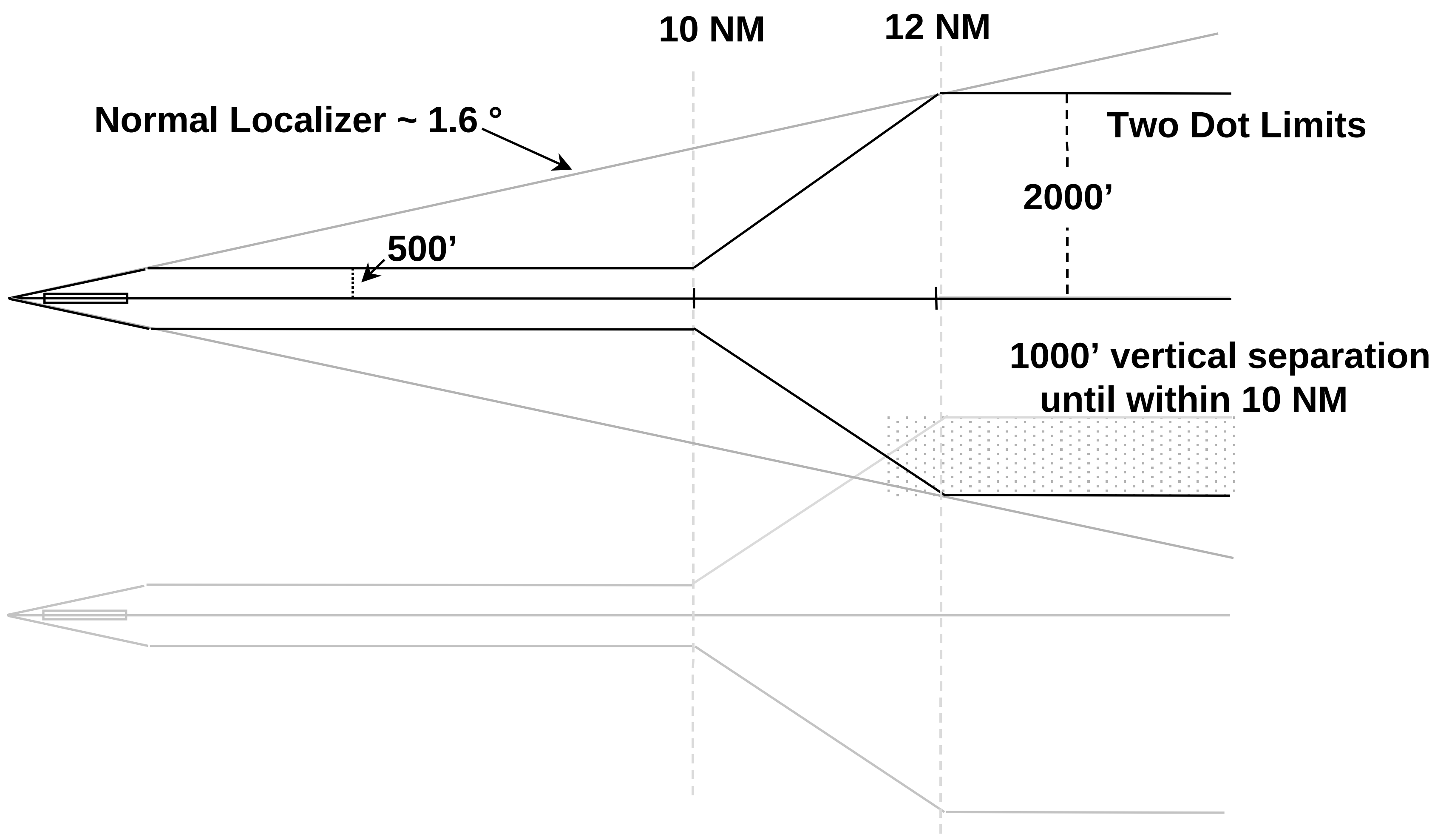


Figure 6. Modified Lateral Path Constraints (Localizer) Based on DGPS

AILS Information Presented in the PFD and ND

(nominal condition, no alert, AILS algorithms activated, one nautical mile display range)

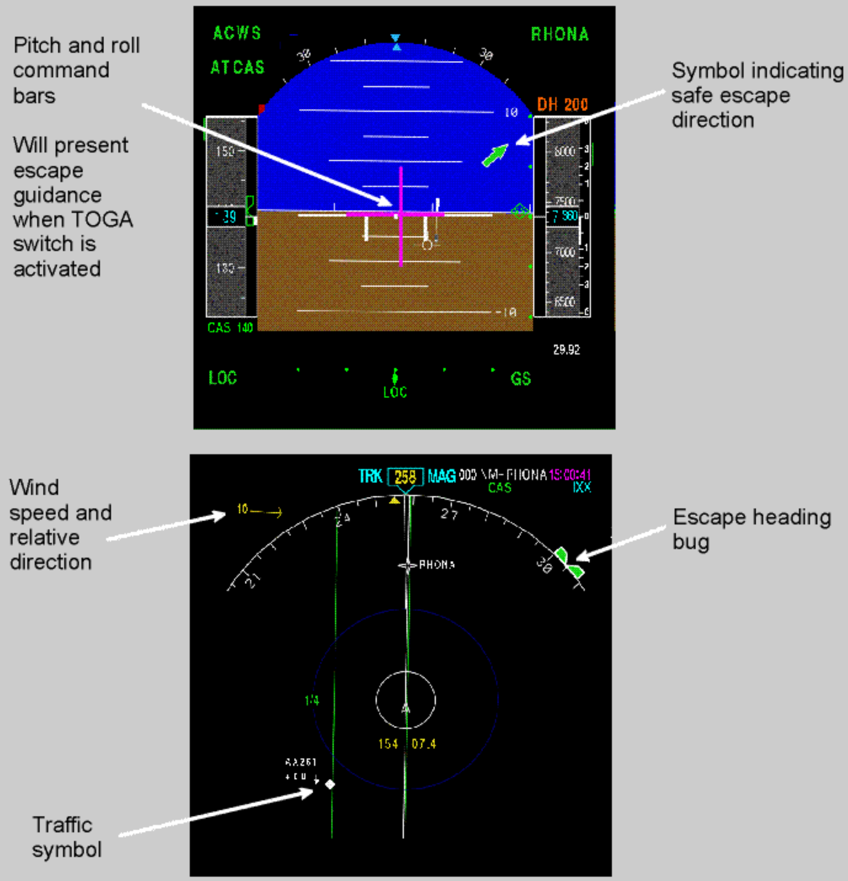


Figure 7. Nominal AILS Display

NoAlert3.cdr

AILS Information Showing Own Airplane Lateral Deviation Caution Alert *(level two alert uses amber color coding)*

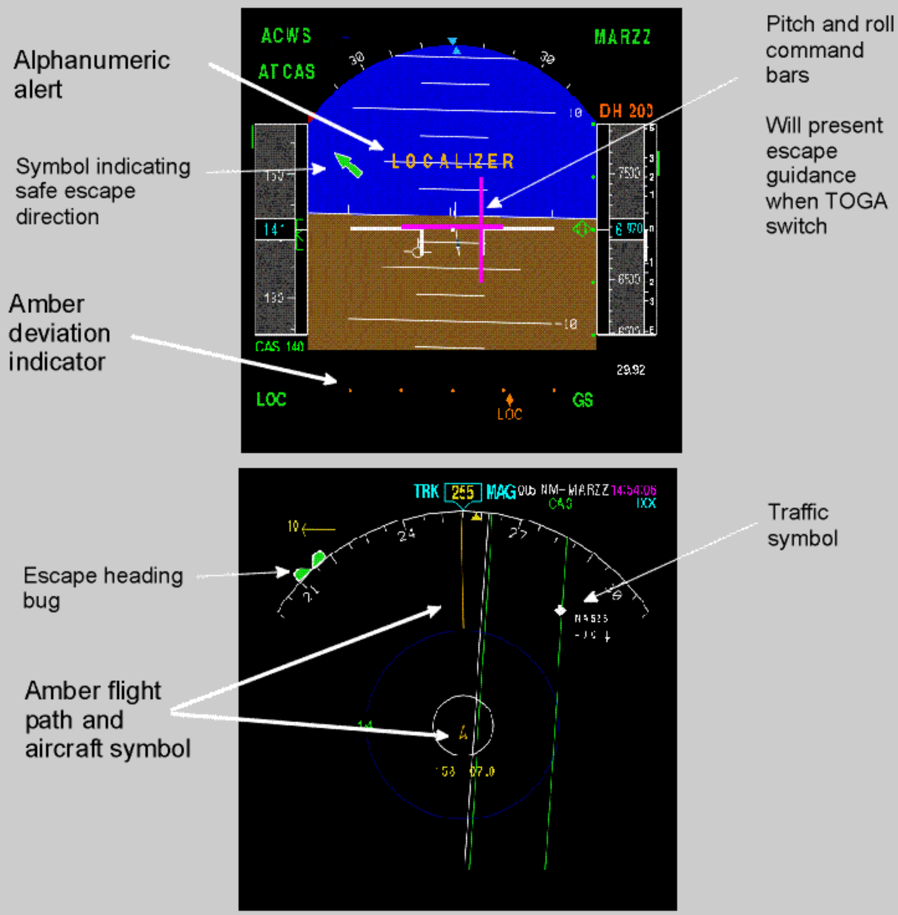


Figure 8. Display localizer deviation configuration

TrafficAlert1.cdr

Traffic Warning, Level Three Alert

(One nautical mile display Range,
red color coding for level three)

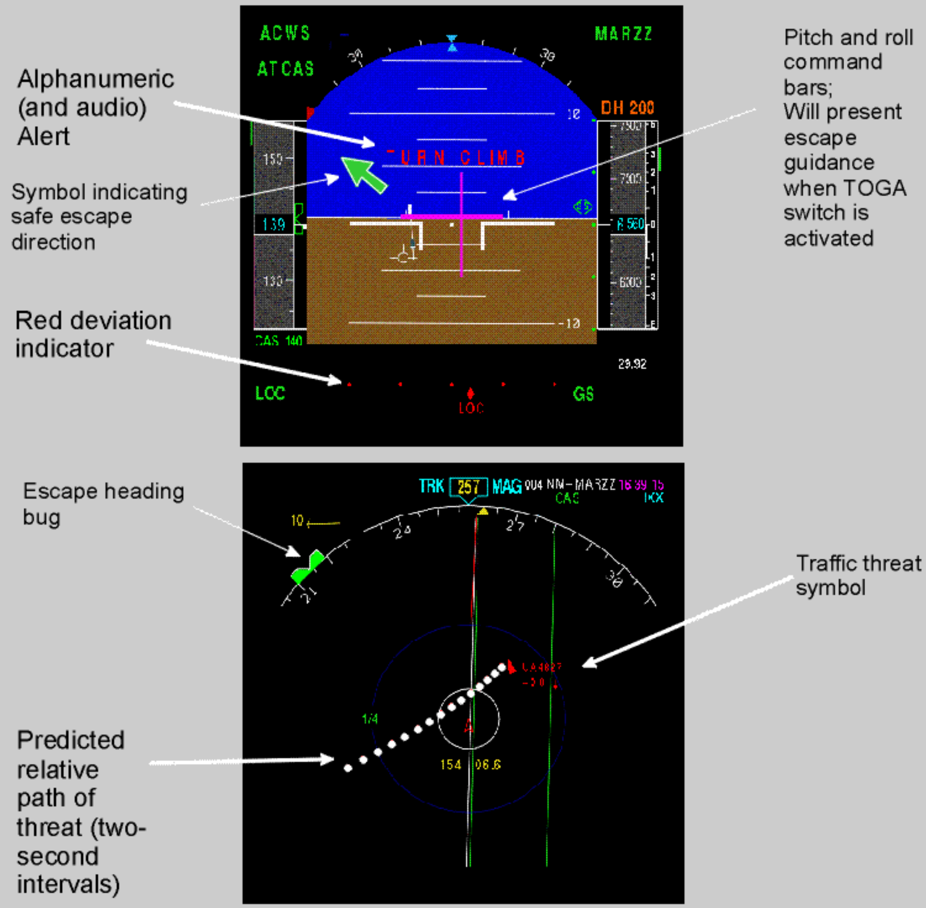


Figure 9. Display with traffic alert

WarnAlrt3.cdr

ï Typically Tower Local Controllers use 15 NM range scaling

10 to 40 NM available in 2NM increments

2 NM range marks

User preference with some variations

ï Target Size on DBRITE display

(Digital Bright Radar Indicator Tower Equipment)

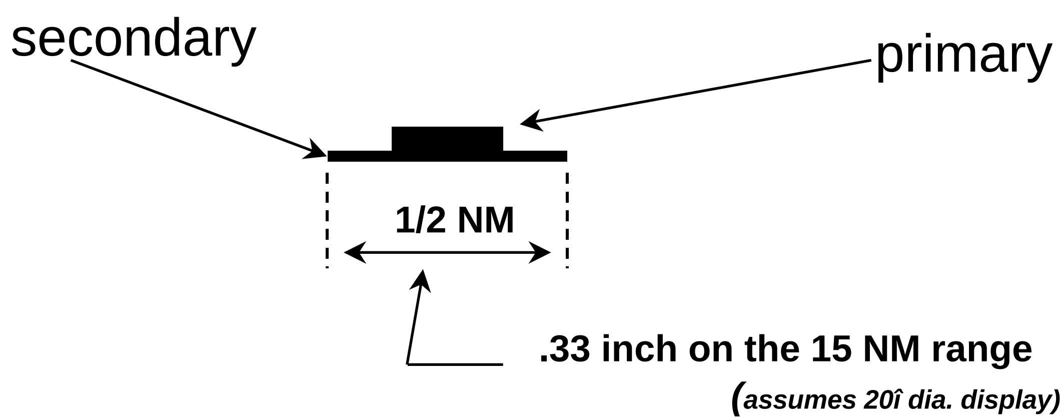
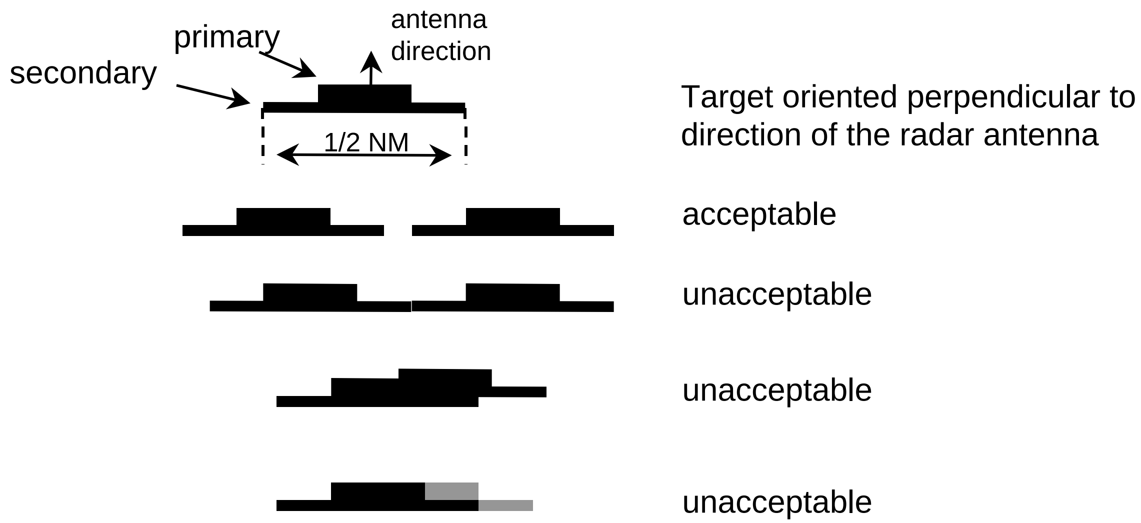


Figure 10. ARTS IIIA/E Radar Display Scaling



ï Typically Tower Local Controllers use 15 NM range scaling (display center to edge)

- Range selections: 10 to 40 NM available in 2 NM increments
- User preference although relatively few variations

ï 1/2 NM target size on DBRITE display

(Digital Bright Radar Indicator Tower Equipment)

ï Rule of thumb: when altitude separation is less than 1000 ft., to accept control, targets should be diverging with green space between

Figure 11. Tower Local Controller Display resolution DBRITE

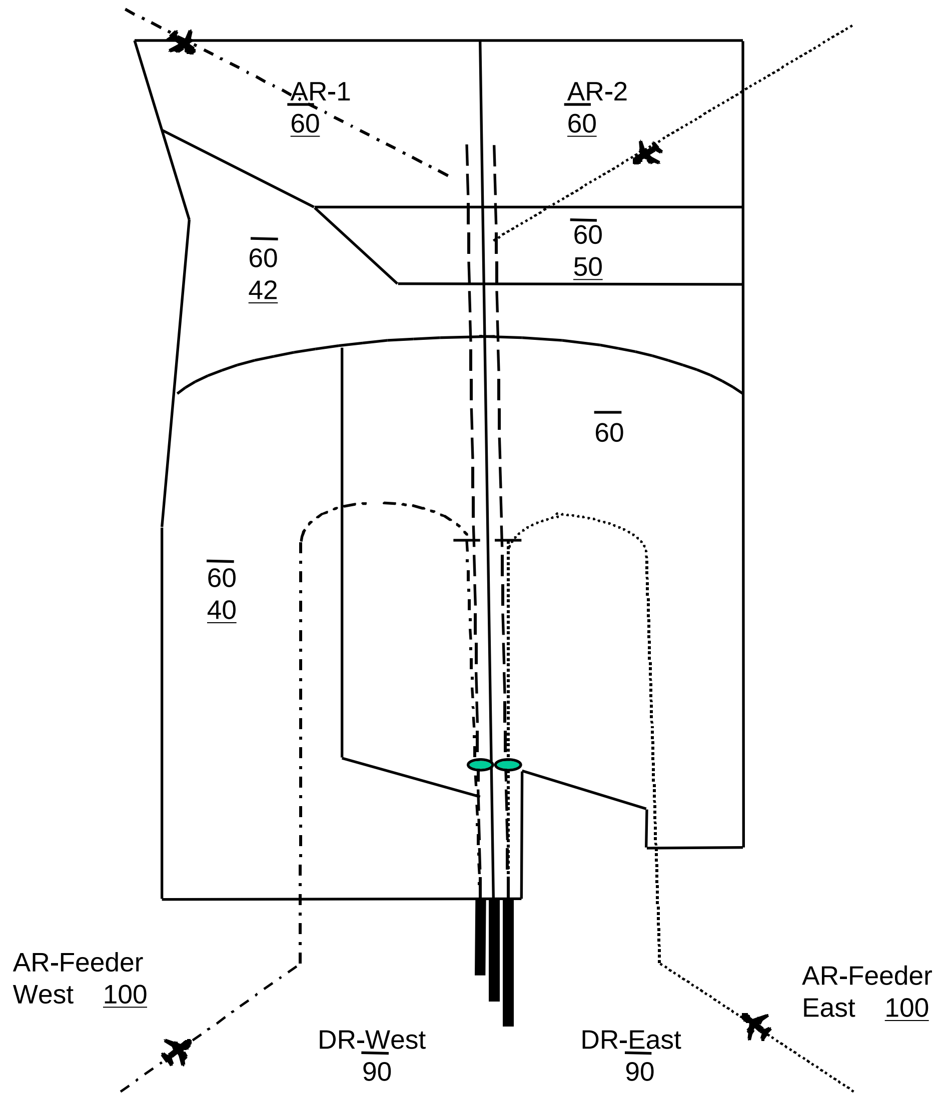


Figure 12. Nominal Traffic Pattern in the Seattle-Tacoma Terminal Area

1. AR-Feeder East hands off Intruder aircraft to AR-2 descending to 6000í.
2. AR-2 descends Intruder to 3000í on downwind.
3. AR-2 turns Intruder approximately 12 mile final, descends aircraft to 2000í, clears aircraft for AILS RWY 16L Straight-In Approach and contact LC-East approximately nine mile final.
4. AR-Feeder West hands off Evader aircraft to AR-1 descending to 6000í.
5. AR-1 descends Evader on downwind to 4000í.
6. AR-1 turns Evader approximately 12 mile final, descends aircraft to 3000í, clears aircraft for AILS RWY 16R Straight In Approach and contact LC-West approximately nine mile final.
7. Prior to FAF the Intruder deviates 30 degrees right of course.
8. The Evader turns to a 205 deg. heading and climbs to 4000í.
9. The CI coordinates with AR-1/AR-Feeder West/DR-West. AR-1 approves downwind RWY 16R or both aircraft and 4000í
10. CI and CC coordinate transfer of control of both aircraft back to AR-1.
11. LC-West turns Evader to downwind climbing to 4000í and switches aircraft to AR-1.
12. LC-East turns Intruder to downwind climbing to 4000í and switches aircraft to AR-1.
13. Both aircraft are sequenced back into AR-1ís traffic pattern.

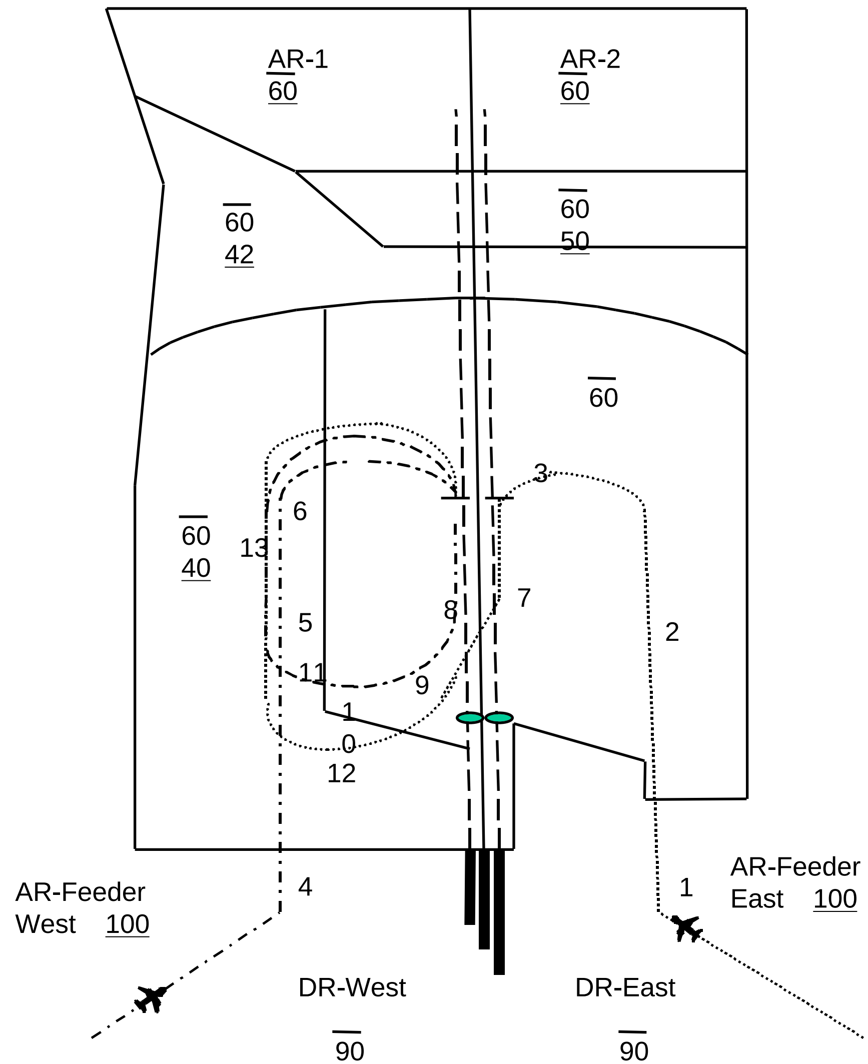


Figure 13. SEA Incident Scenario 1: Straight-In Approach. EEM right of course. Both aircraft returned to AR-1.

1. AR-Feeder West hands off Intruder aircraft to AR-1 descending to 6000í.
2. AR-1 descends Intruder to 4000í on downwind.
3. AR-1 turns Intruder approximately 12 mile final, descends aircraft to 3000í, clears aircraft for AILS RWY 16R Straight-In Approach and contact LC-West approximately nine mile final.
4. AR-Feeder East hands off Evader aircraft to AR-2 descending to 6000í.
5. AR-2 descends Evader on downwind to 3000í.
6. AR-2 turns Evader approximately 12 mile final, descends aircraft to 2000í clears aircraft for AILS RWY 16L Straight-In Approach and contact LC-East approximately nine mile final.
7. Prior to FAF the Intruder deviates 30 degrees left of course.
8. The Evader turns to a 115 degree heading and climbs to 3000í.
9. The CI coordinates with AR-2/AR-Feeder East/ DR-East. AR-2 approves downwind RWY 16L for both aircraft climbing to 3000í.
10. CI and CC coordinate transfer of control of both aircraft back to AR-2.
11. LC-East turns Evader to downwind climbing to 3000í and switches aircraft to AR-2.
12. LC-West turns Intruder to downwind climbing to 3000í and switches aircraft to AR-2.
13. Both aircraft are sequenced back into AR-2ís traffic pattern.

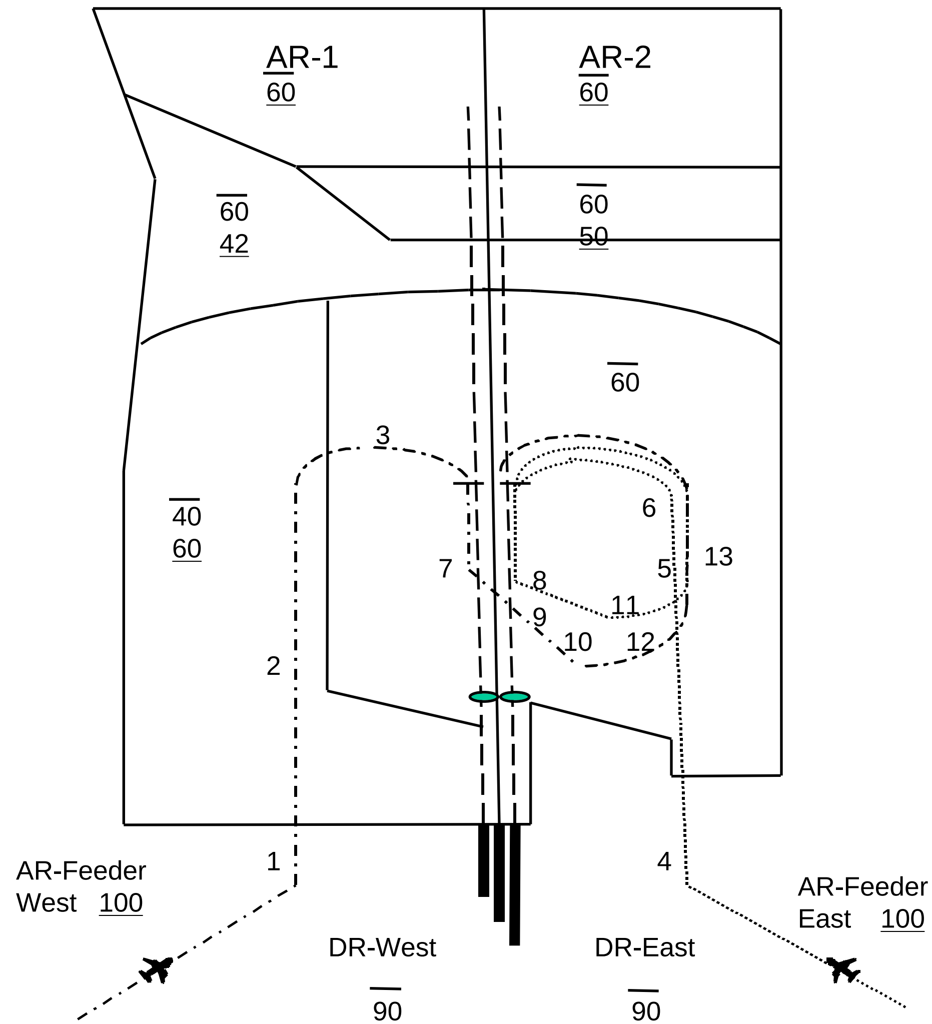


Figure 14. SEA Incident Scenario 2: AILS RWY 16L Straight-In Approach. EEM left of course. Both aircraft returned to AR-2.

1. Both aircraft executing AILS RWY 16L/R straight-in approaches. On final, both aircraft are on their respective LC frequencies.
2. The aircraft on AILS RWY 16R approach executes a missed approach and climbs to 2000í on the SEA R-158.
3. LC-West/CC coordinates with DR-East/West and AR-Feeder West for missed approach.
4. Aircraft told to switch to DR-West frequency for vectors to the approach pattern.

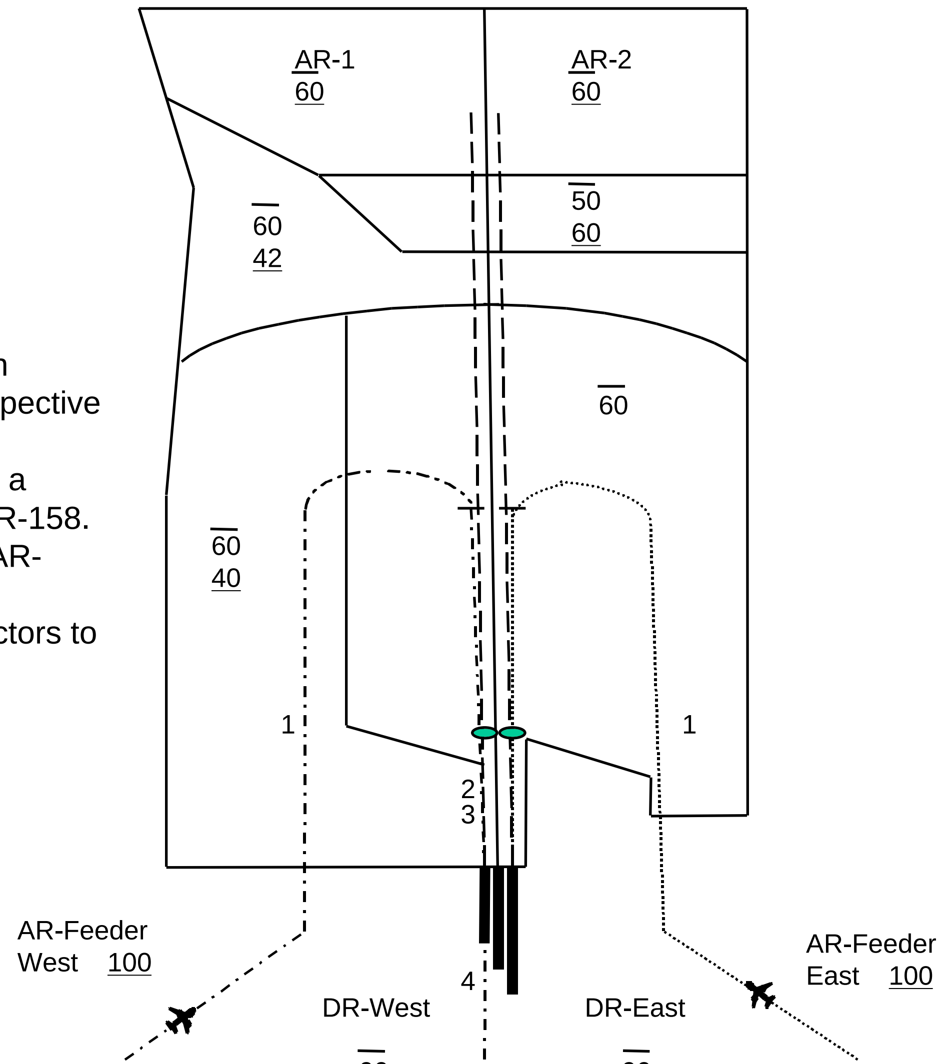


Figure 15. SEA Incident Scenario 3: Straight-In Approaches. Missed approach on RWY 16R.

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1. Aircraft making AILS RWY 16L/R approaches. On final, the Intruder is on LC-East frequency and the Evader is on LC-West frequency.
2. The Intruder drifts 30 degrees right of course.
3. The Evader executes an EEM.
4. CC coordinates with AR-1 for downwind turn.
5. CC points out traffic to DR-West and AR-Feeder West.
6. AR-1 instructs CC to turn aircraft on downwind climbing to 5000í.
7. LC-West turns Evader downwind RWY 16R climbing to 5000íand switches aircraft to AR-1 frequency.
8. LC-East turns Intruder downwind RWY 16R climbing to 5000íand switches aircraft to AR-1 frequency.
9. AR-1 climbs both aircraft to 6000í due to traffic going into BFI, and extends downwind to turn base-leg approximately 20 miles north.
10. AR-1 sequences traffic with BFI traffic and clears both aircraft for AILS RWY 16R approach.

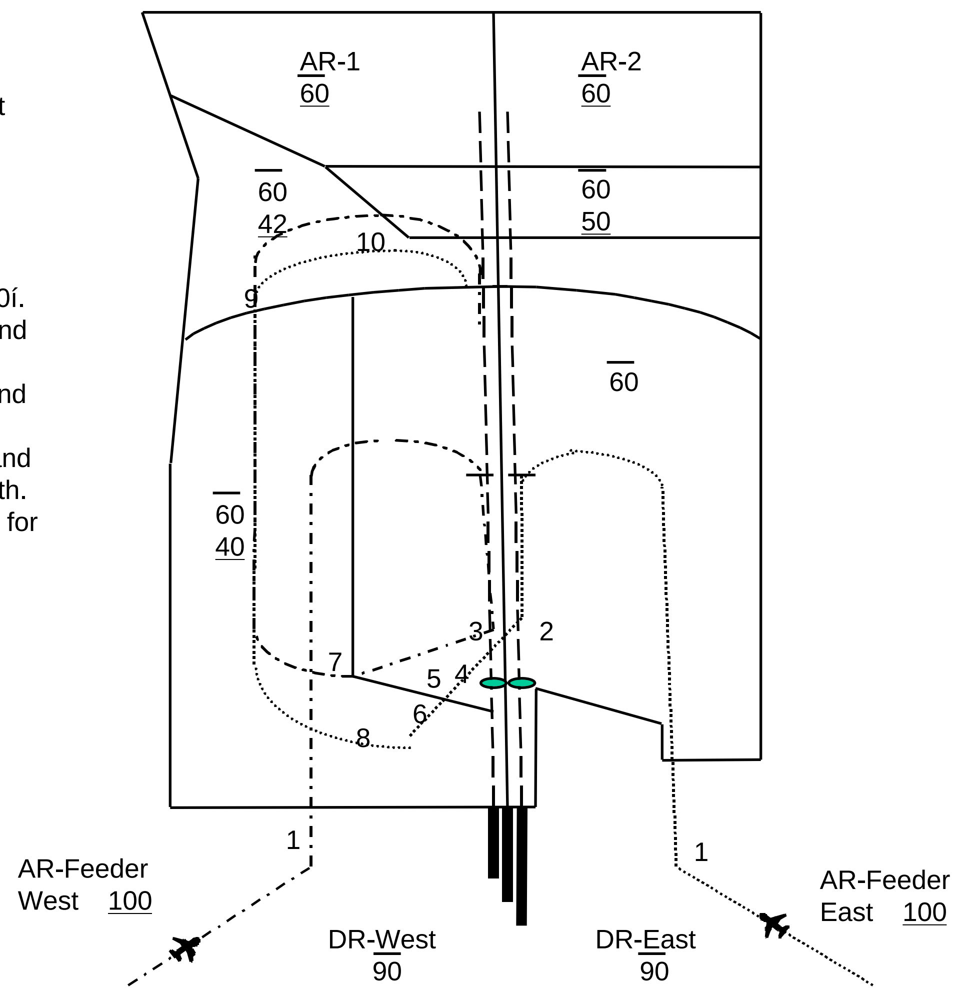
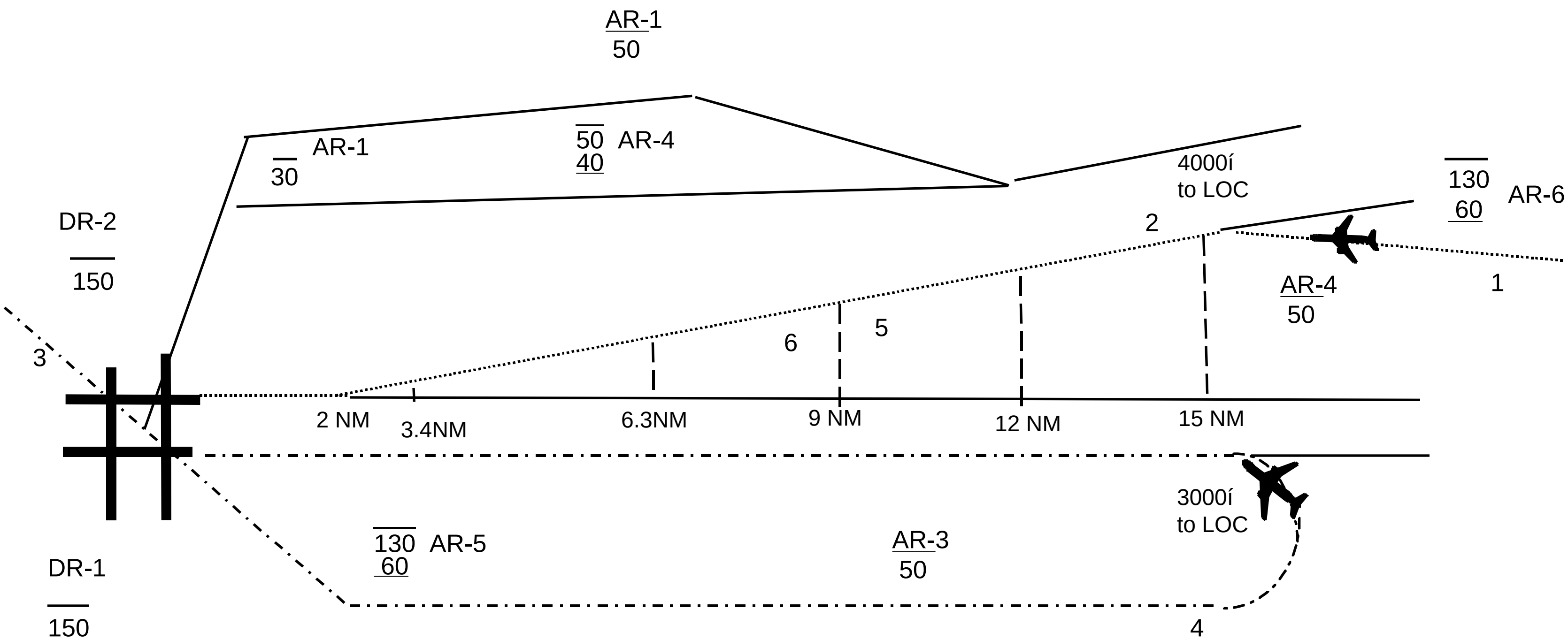
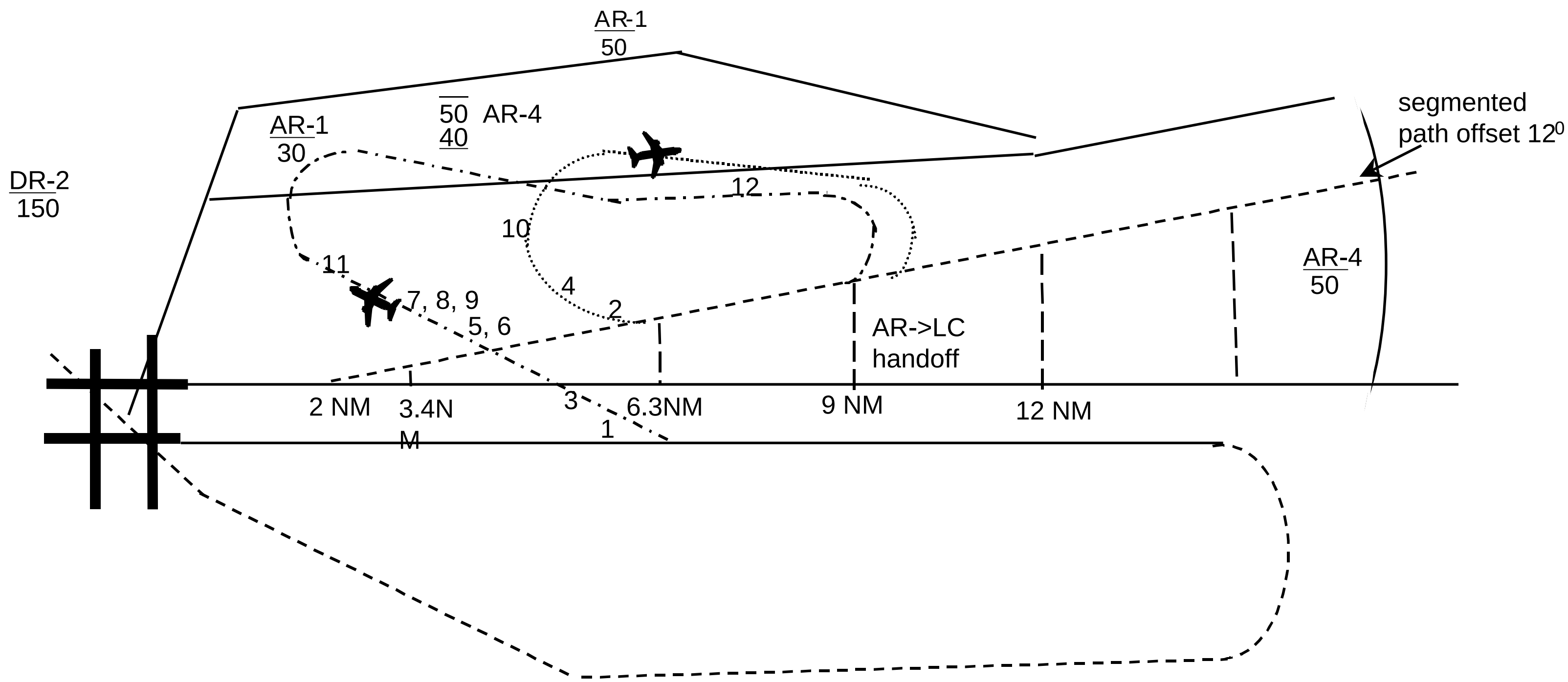


Figure 16. SEA Incident Scenario 4, Straight-in approach. Approaches to BFI in progress. EEM right of course. Both aircraft returned to AR-1 for extended downwind.



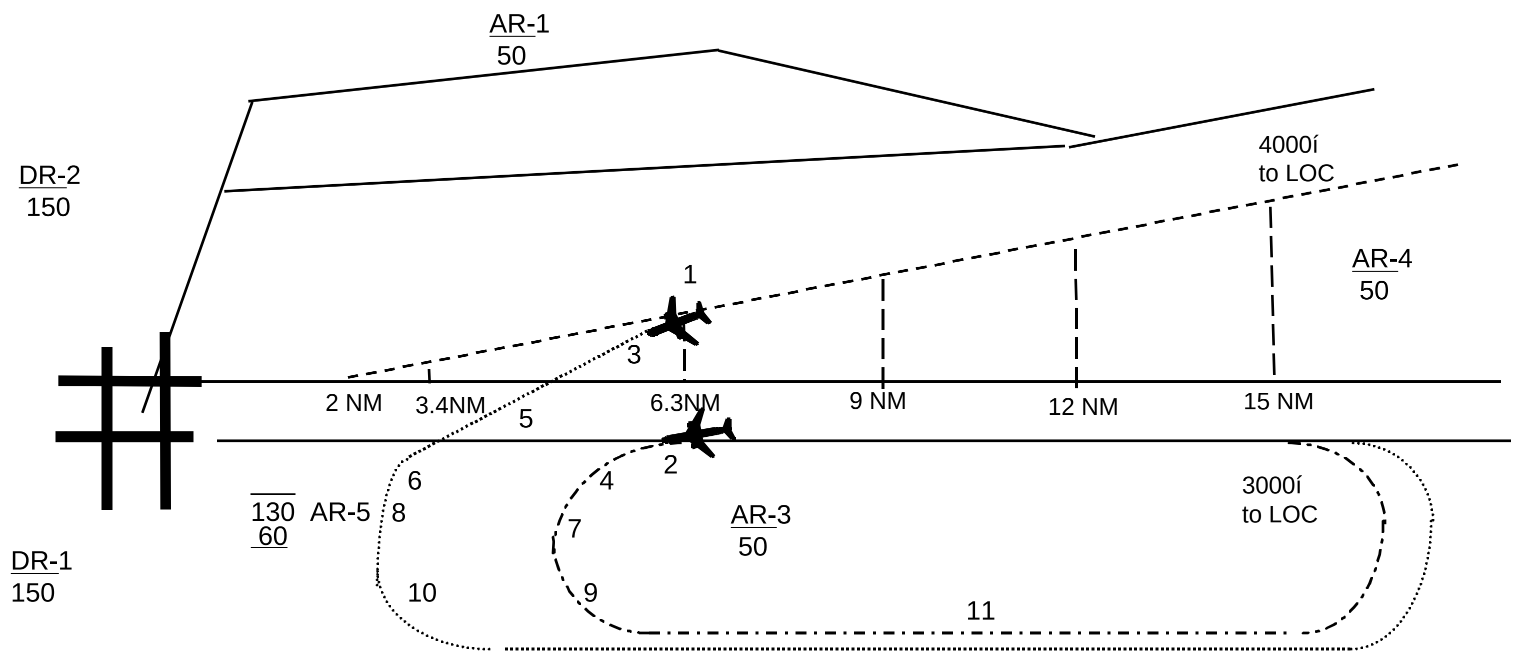
1. AR-6 hands off aircraft to AR-4 on a course parallel to RWY 28R, north of course to intercept the segmented approach course at approximately 15 NM, descending to 5000í.
2. AR-4 descends the aircraft to 4000í and clears it for the AILS RWY 28R Segmented Approach.
3. AR-5 hands off aircraft to AR-3 southeast bound from over the SFO airport descending to 5000í.
4. AR-3 descends the aircraft to turn final at 3000í at 15 NM and clears it for an AILS RWY 28L approach.
5. Both aircraft contact the tower LC and change to AILS Monitor frequency at approximately nine miles on final.
6. The tower LC clears the aircraft to land.

Figure 17. SFO Nominal Segmented Approach (traffic moderate, no intrusion incident)



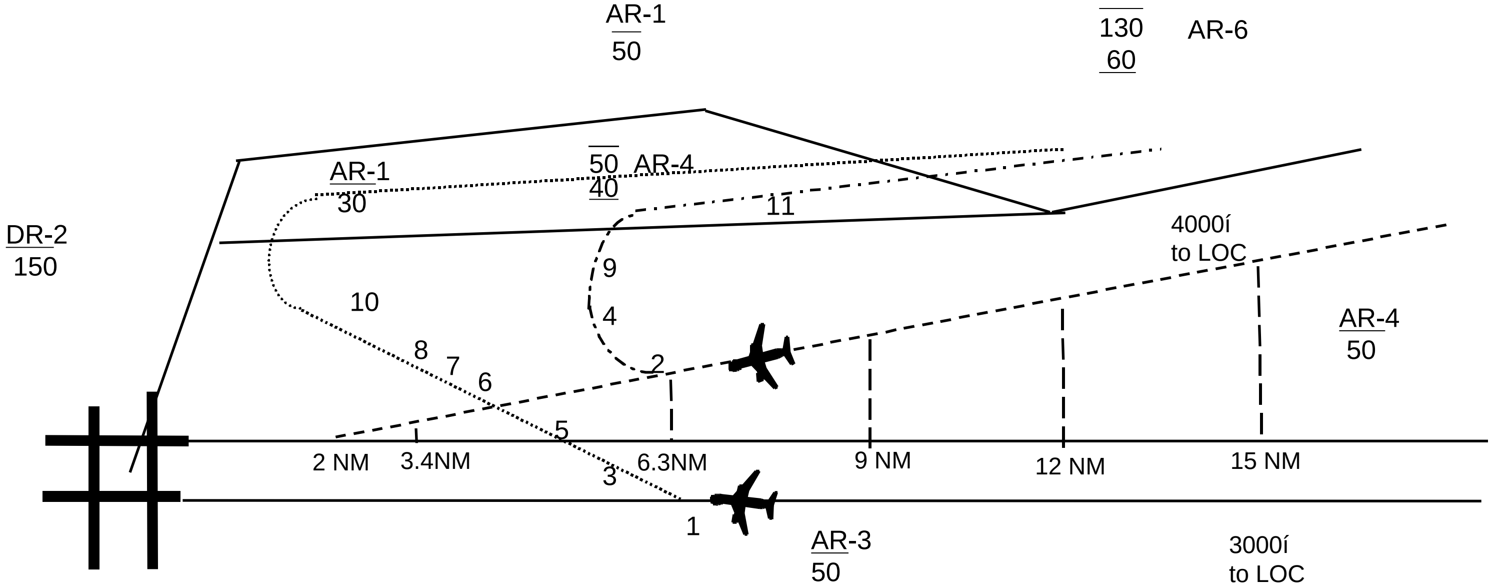
1. Intruder drifts right 30-degrees, aircraft targets converge.
2. Evader executes an EEM climbing right turn to 4000í via 350-degree heading.
3. AR-4/1/DR-2 notified by CC through CI.
4. Targets radar identified.
5. Both targets are flashed at AR-4 for hand-off.
6. CC obtains clearance from CI through AR-1 ìboxî for both aircraft.
7. AILS Monitor (or CC/CI) request downwind for both aircraft from AR-4.
8. CC/CI coordinates 2000í through AR-1 ìboxî for both aircraft.
9. AR-4 approves downwind, 2000í and accepts hand-off of both aircraft.
10. Evader turned to downwind heading, assigned 2000í and switched to AR-4.
11. Intruder turned to downwind heading, assigned 2000í and switched to AR-4.
12. AR-4 vectors both aircraft back into the approach sequence.

Figure 18. SFO Incident Scenario 1. Intrusion to right of course, both aircraft returned to AR-4.



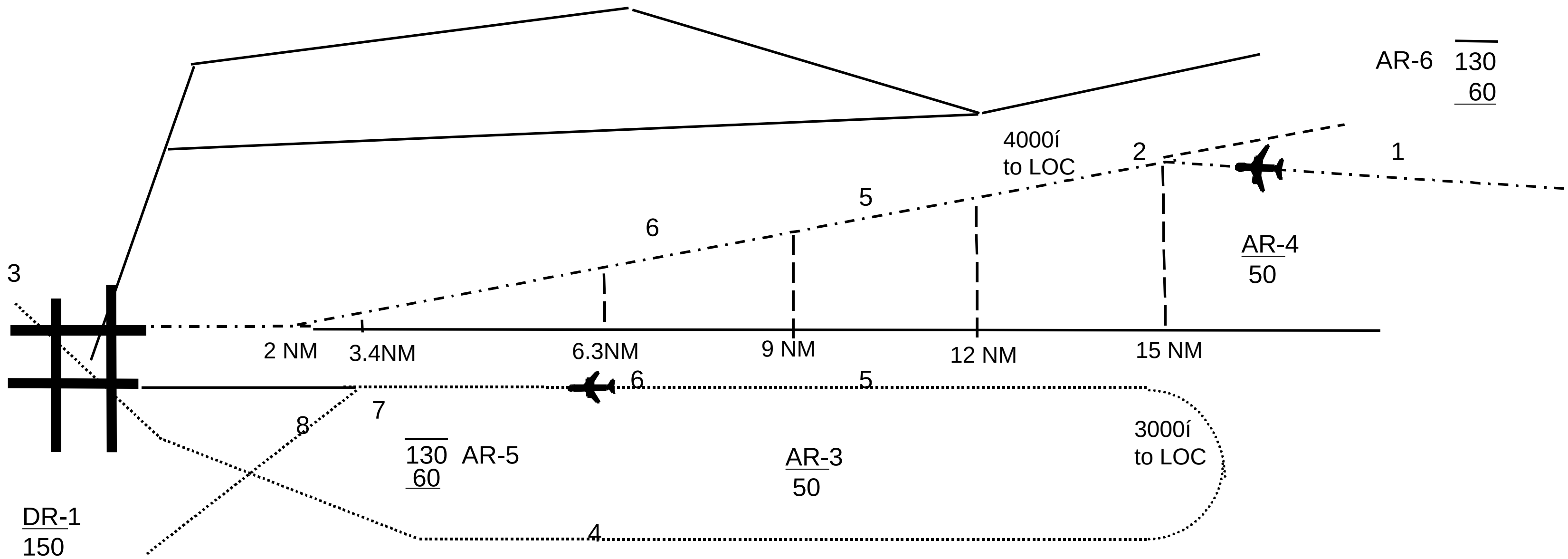
1. Intruder drifts left 30 degrees on approach to RWY 28R.
2. Evader executes EEM, climbing left turn to 4000í via 225 degrees.
3. AR-3/5/DR-1 notified by Coordinator (CI).
4. Targets radar identified.
5. Both targets are electronically flashed on the display at AR-3 for handoff.
6. CI obtains clearance to turn both aircraft downwind and climb to 4000í.
7. AILS Monitor requests downwind for both aircraft from AR-3.
8. AR-3 approves downwind, climb to 4000í and accepts handoff of both aircraft.
9. Evader turned to downwind heading, climbed to 4000í and switched to AR-3.
10. Intruder turned to downwind heading, climbed to 4000í and switched to AR-3.
11. AR-3 vectors both aircraft back into the approach queue.

Figure 19. SFO Incident Scenario 2. Intrusion to left of course, both aircraft returned to AR-3.



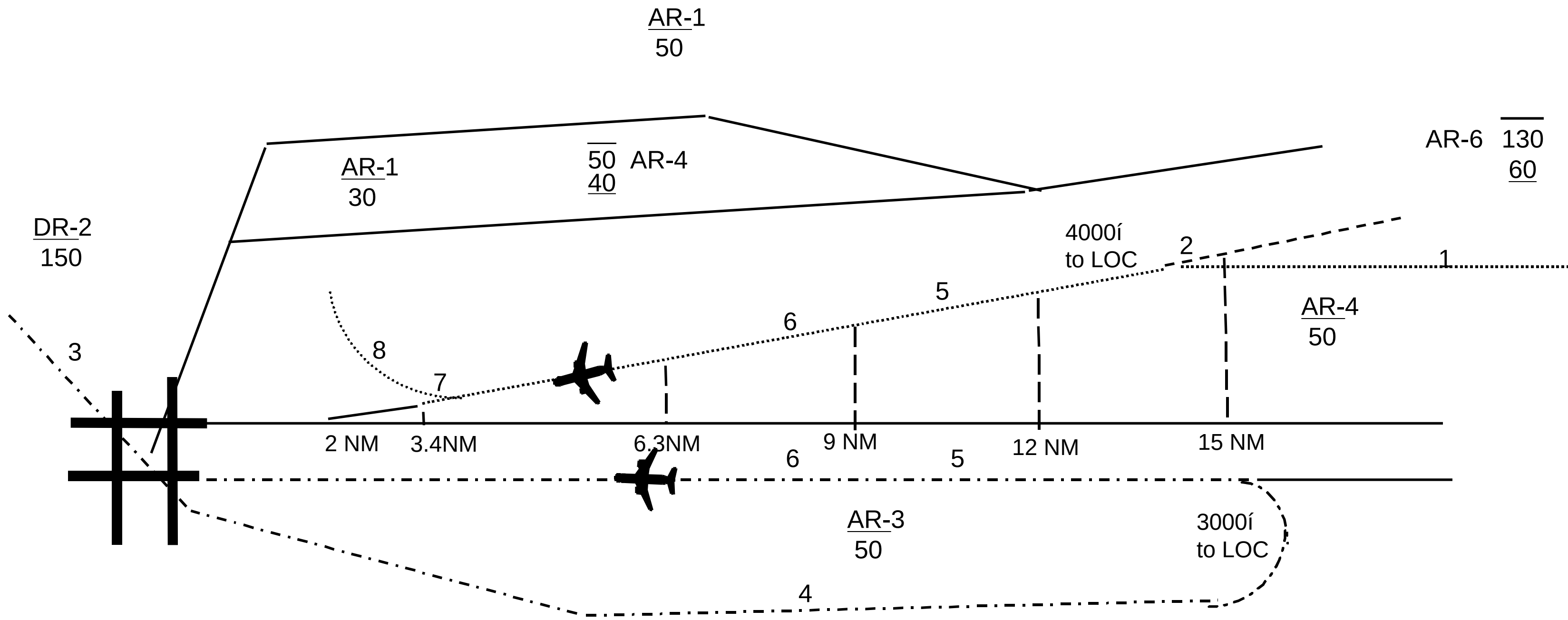
1. Intruder drifts right 30 degrees on approach to RWY 28L.
2. Evader executes EEM.
3. AR-4/1/DR-2 notified by Coordinator (CI).
4. Targets radar identified.
5. Both targets are electronically flashed on the display at AR-4 for handoff.
6. CI obtains clearance through AR-1 airspace for both aircraft.
7. AILS Monitor request downwind for both aircraft from AR-4.
8. AR-4 approves downwind , climb both aircraft to 5000í and switched to AR-6.
9. Evader turned to downwind heading, climbed to 5000í and switched to AR-6.
10. Intruder turned to downwind heading, climbed to 5000í and switched to AR-6.
11. AR-6 climbs aircraft to 7000í and sequences them with other traffic for AR-4/3.

Figure 20. SFO Incident Scenario 3. Intrusion to right, both aircraft handed off to AR-6.



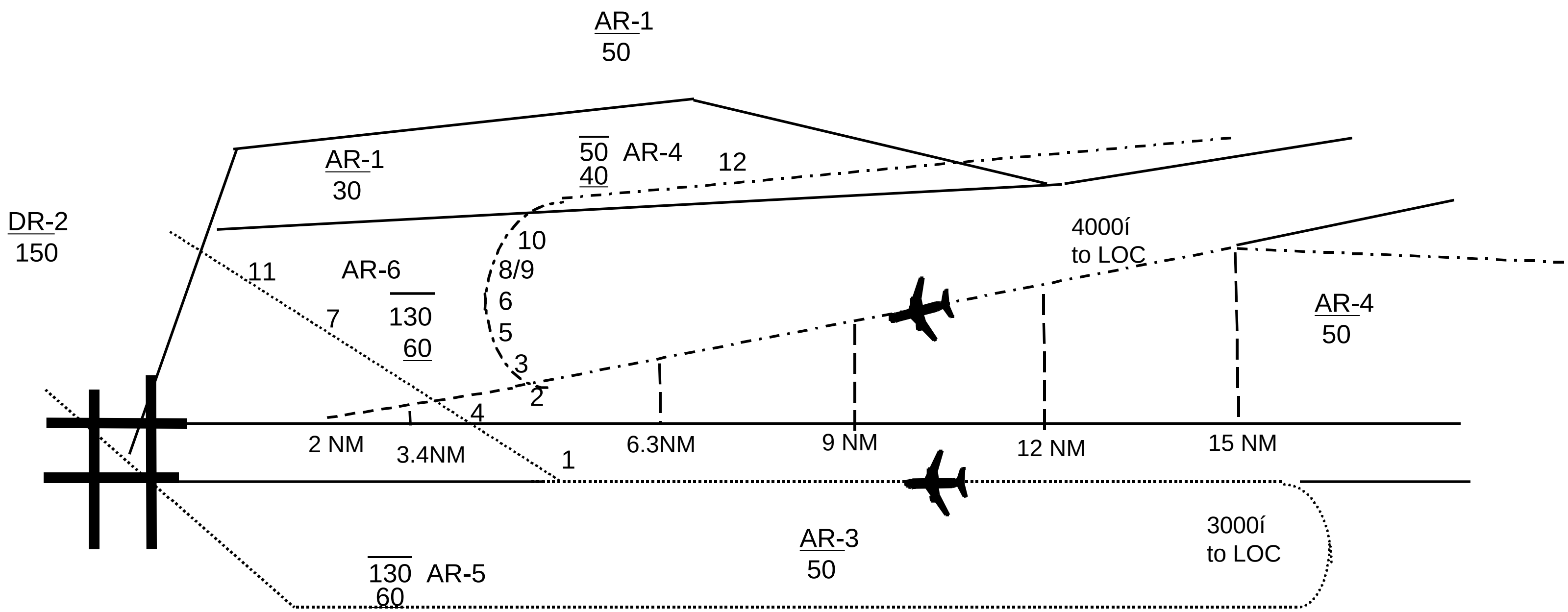
1. AR-6 hands off aircraft to AR-4 on a course parallel to RWY 28R, north of course, to intercept the segmented approach course at approximately 15 NM, descending to 5000í
2. AR-4 clears the aircraft to 4000íand when established on the localizer, clears the aircraft for an AILS RWY 28R Segmented approach.
3. AR-5 hands off aircraft to AR-3 southeast bound from over the SFO airport descending to 5000í.
4. AR-3 descends the aircraft to 3000í on base leg to final and clears the aircraft for an AILS RWY 28L approach.
5. Both aircraft contact the tower LC and change to the AILS Monitor frequency at approximately nine miles on final.
6. The tower LC clears the aircraft to land.
7. The aircraft making the approach to RWY 28L executes a missed approach at the missed approach point, climbing left turn to 3000í via heading 235 degrees.
8. CI coordinates with AR-3/5/DR-1.

Figure 21. SFO Incident Scenario 4. RWY 28L Straight-In side missed approach.



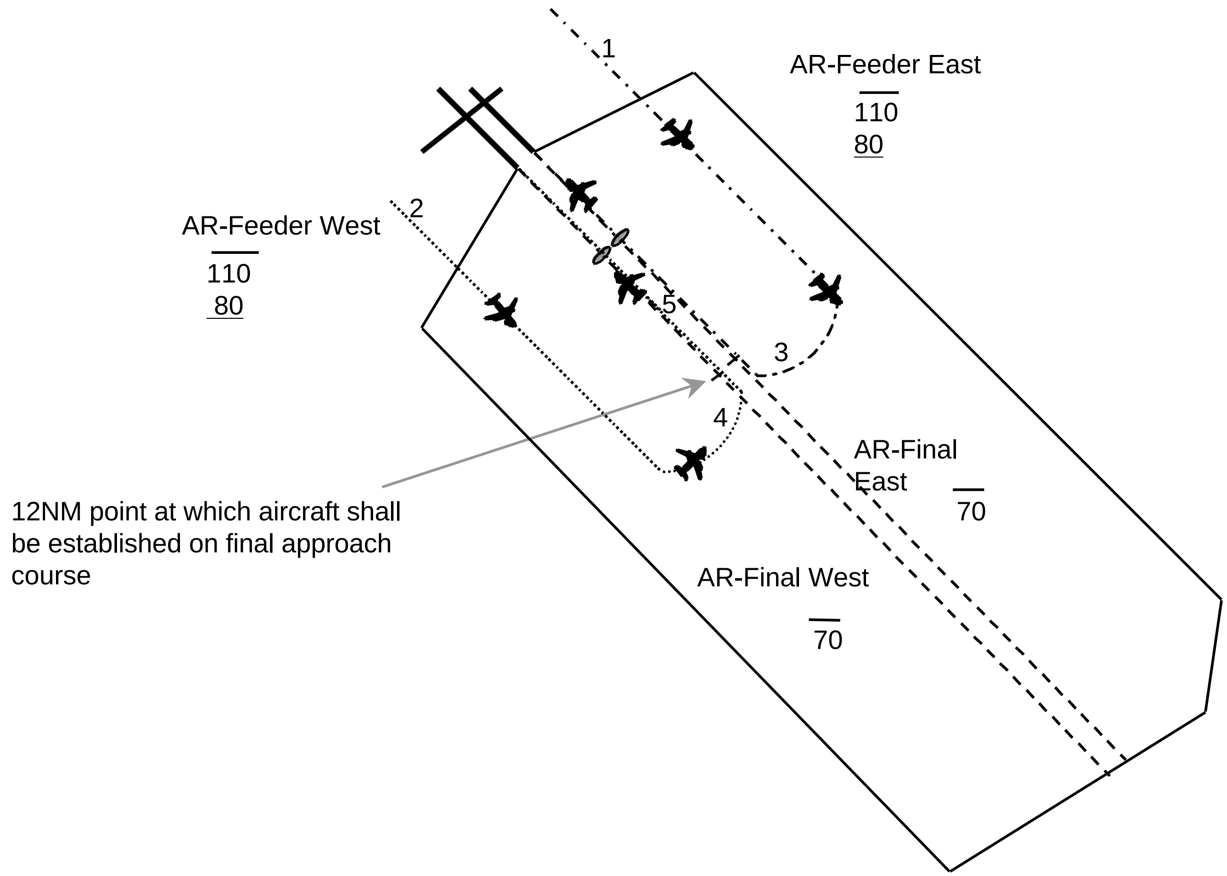
1. AR-6 hands off aircraft to AR-4 on a course parallel to RWY 28R, north of course to intercept the segmented approach course at approximately 15 NM, descending to 4000í.
2. When established on the localizer, AR-4 clears the aircraft for an AILS RWY 28R Segmented approach.
3. AR-5 hands off aircraft to AR-3 southeast bound from over the SFO airport descending to 5000í.
4. AR-3 descends the aircraft to 3000í on base leg to final and clears the aircraft for an AILS RWY 28L approach.
5. Both aircraft contact the tower LC and change to the AILS Monitor frequency at approximately nine miles on final.
6. The tower LC clears the aircraft to land.
7. The aircraft making the approach to RWY 28R executes a missed approach at the missed approach point, climbing right turn to 4000í via heading 350 degrees.
8. CI coordinates with AR-4/1/6.

Figure 22. SFO Incident Scenario 5. RWY 28R segmented approach, aircraft missed approach.



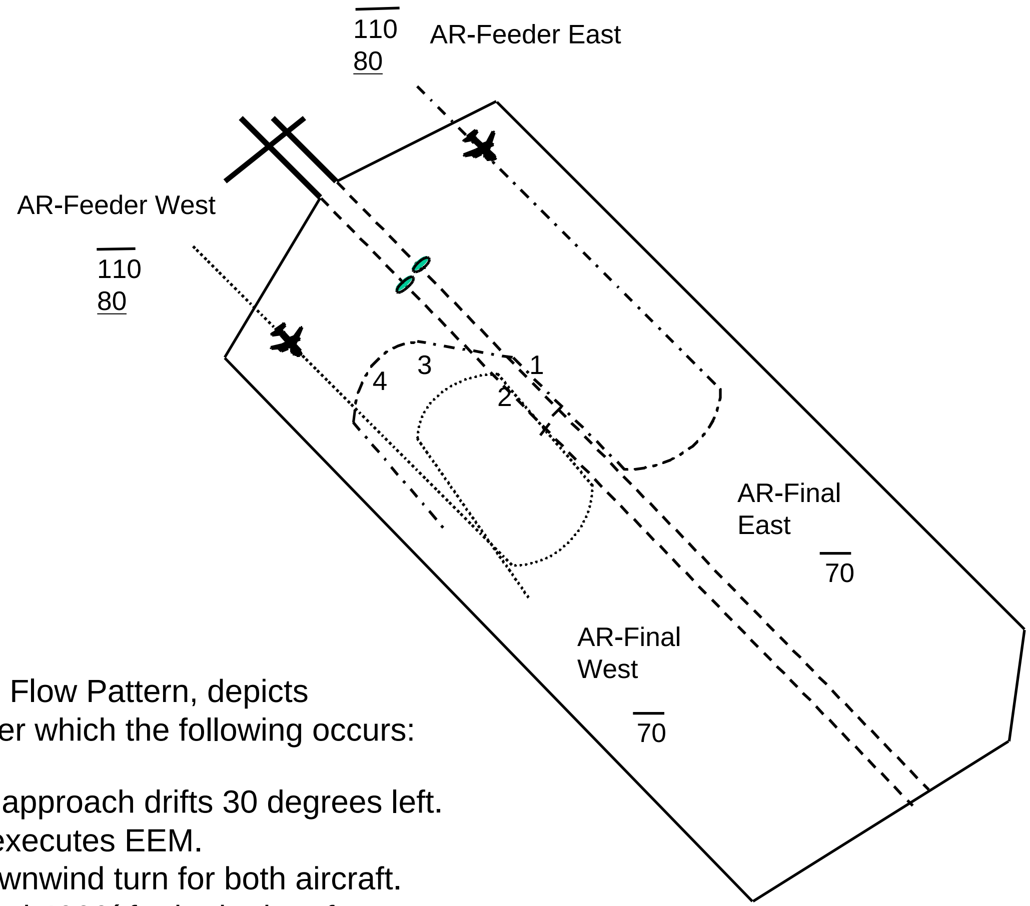
1. Intruder drifts right 30 degrees, aircraft targets converge.
2. Evader executes EEM, climbing right turn to 4000í via heading 350 degrees.
3. AR-4/1/6/DR-2 notified by CI.
4. Radio contact loss with Intruder aircraft flying northwest bound.
5. Evader aircraft radar identified and electronically flashed to AR-4 for handoff.
6. CI obtains clearance through AR-1 airspace.
7. CI points out Intruder aircraft to DR-2 and AR-6.
8. AILS Monitor request downwind for Evader aircraft from AR-4.
9. AR-4 approves downwind and climb to 5000í for Evader and switch to AR-6 frequency.
10. Evader turned to downwind heading, climbed to 5000í and switched to AR-6.
11. Intruder enters DR-2 airspace northwest bound.
12. AR-6 climbs Evader to 7000í and sequences it with other traffic for AR-4.

Figure 23. SFO Incident Scenario 6. Lost radio contact with the Intruder.



1. AR-Feeder East hands aircraft off to AR-Final East descending to 7000-8000í.
2. AR-Feeder West hands aircraft off to AR-Final West descending to 7000-8000í.
3. AR-Final East turns aircraft in for 12 mile final at 4000í and clears aircraft for AILS approach.
4. AR-Final West turns aircraft in for 12 mile final at 3000í and clears aircraft for AILS approach.
5. Aircraft are changed to tower Local Control frequency at approximately 9 miles for landing clearance.

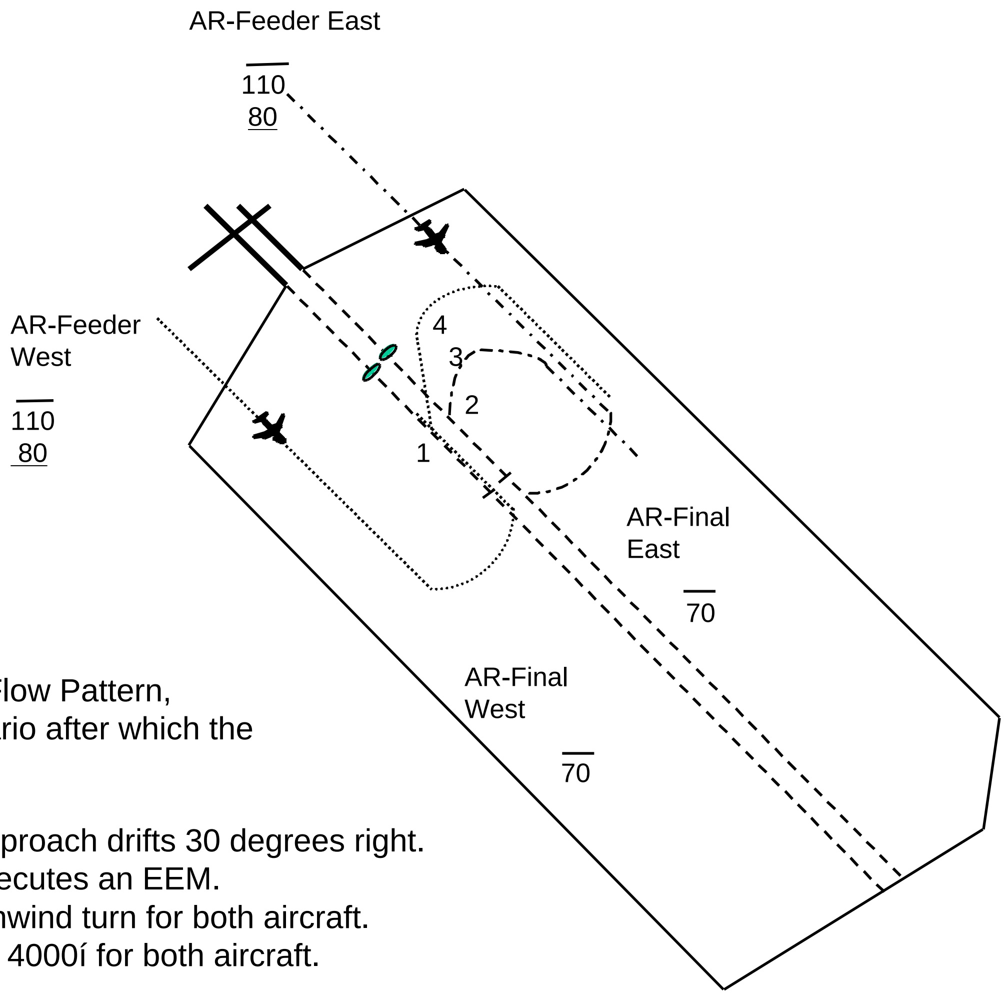
Figure 24. MSP Terminal Area, Nominal Traffic Flow Pattern.



Note: Figure 24, Nominal Traffic Flow Pattern, depicts the initial part of this scenario after which the following occurs:

1. Intruder aircraft on RWY 30R approach drifts 30 degrees left.
2. Evader aircraft on RWY 30L executes EEM.
3. CC coordinates with CI for downwind turn for both aircraft.
4. CI approves downwind turn and 4000í for both aircraft.

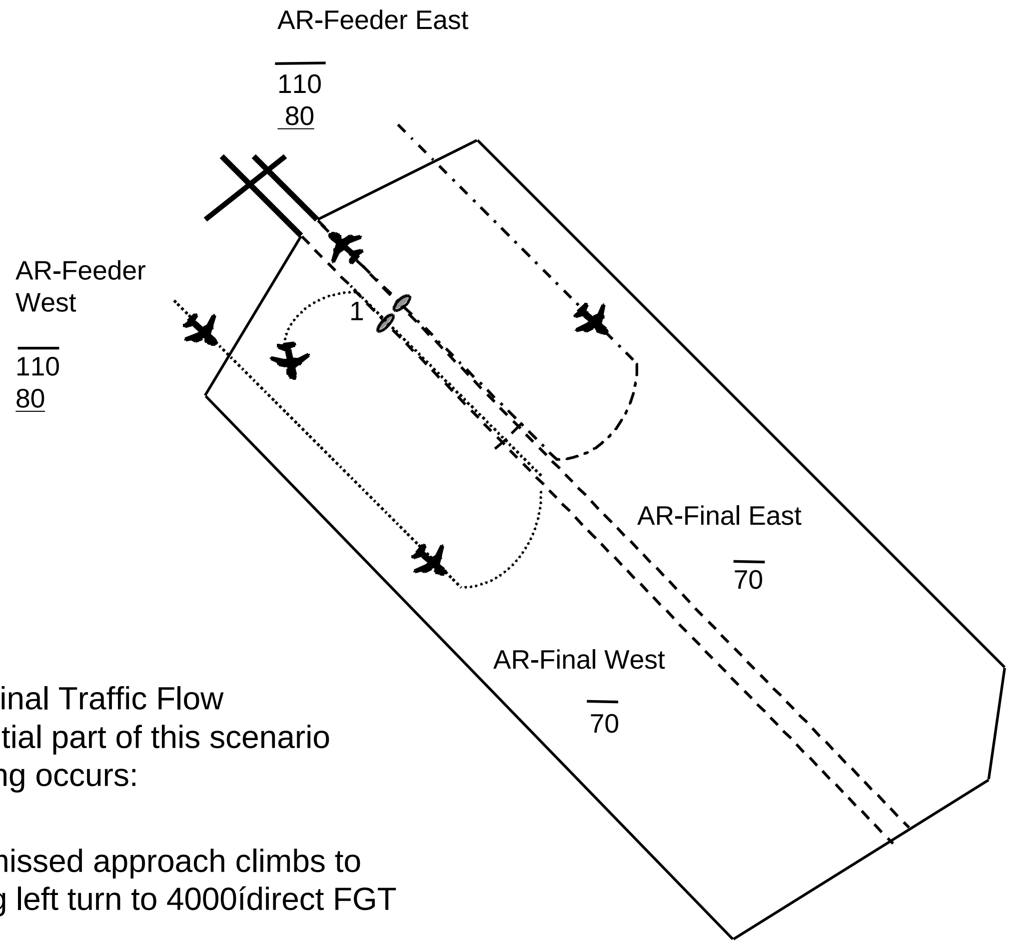
Figure 25. MSP Incident Scenario 1. Aircraft on approach to RWY 30R deviates to the left aircraft on RWY 30L to escape left.



Note: Figure 24, Nominal Traffic Flow Pattern, depicts the initial part of this scenario after which the following occurs:

1. Intruder aircraft on RWY 30L approach drifts 30 degrees right.
2. Evader aircraft on RWY 30R executes an EEM.
3. CC coordinates with CI for downwind turn for both aircraft.
4. CI approves downwind turn and 4000í for both aircraft.

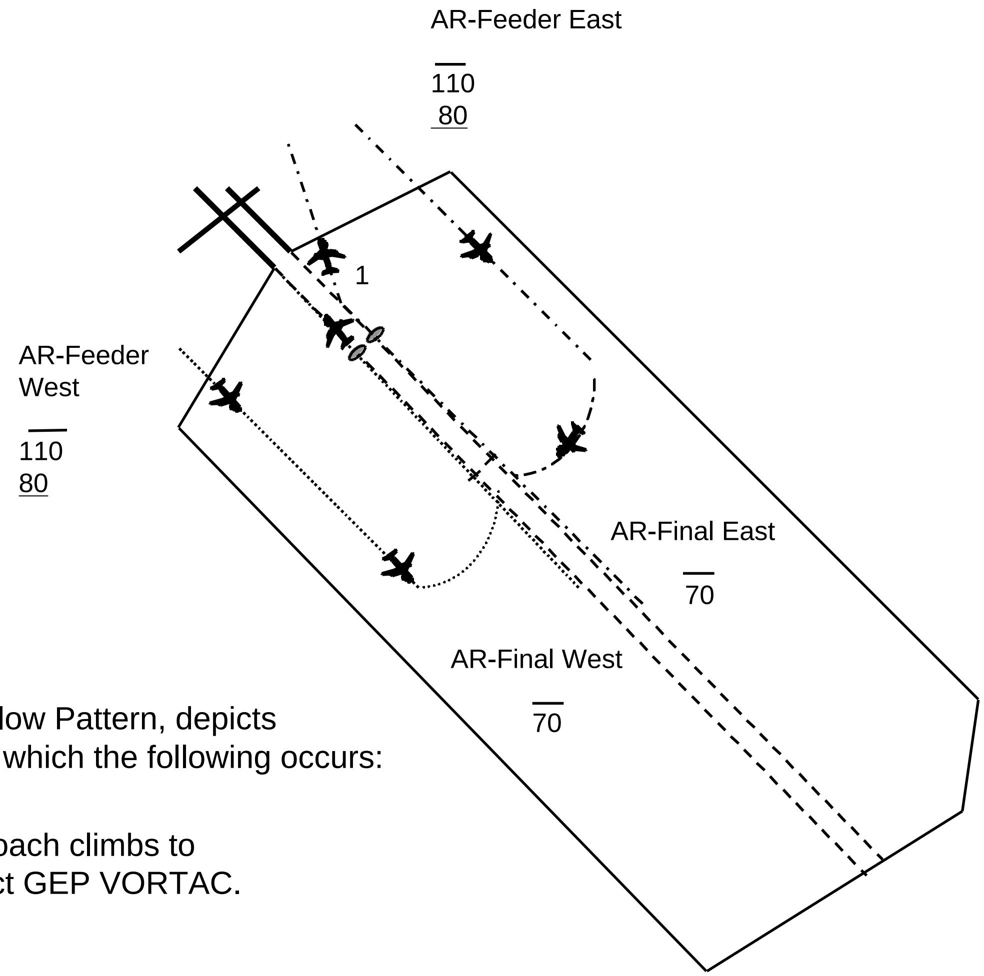
Figure 26. MSP Incident Scenario 2: Aircraft on RWY 30L approach deviates to the right, aircraft on RWY 30R approach evades to the right.



Note: Figure 24, Nominal Traffic Flow Pattern, depicts the initial part of this scenario after which the following occurs:

1. Aircraft executing missed approach climbs to 1500í then climbing left turn to 4000ídirect FGT VORTAC.

Figure 27. MSP Incident Scenario 3. Aircraft on approach to RWY 30L executes a missed approach to the left.



Note: Figure 24, Nominal Traffic Flow Pattern, depicts
the initial part of this scenario after which the following occurs:

1. Aircraft executing missed approach climbs to
1500í then right turn to 5000í direct GEP VORTAC.

Figure 28. MSP Incident Scenario 4. Aircraft on approach to RWY 30R executes a missed approach to the right.